A PRACTICAL TREATISE

ON

MODERN SCREW-PROPULSION.

ILLUSTRATED WITH

FIFTY-TWO PLATES, AND ONE HUNDRED AND THREE WOODCUTS.

BY

N. P. BURGH, Engineer.

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PREFACE.

I FELT confident when I began to write this work, that its success was a certainty; and that my appeal to the Leading Marine Engineers to contribute ARTICLES on their best practice, with DRAWINGS and INFORMATION of Modern Screw-Propulsion would be most liberally responded to—as it has been; and *I* am not surprised at it, for this reason, that when this work was commenced there was *no* practical information published similar to what it contains, so it became then almost a duty owed to the profession by its leading members to supply amongst themselves what was required; and when I was personally selected by them as the Editor, as well as an authority for the purpose, I knew a task was imposed on me that required attention, energy, and time. The way I set about my duties was to consider, first, how to arrange the matter that I had to handle; secondly, *who* to appeal to for the information; and, thirdly, to get it.

How I have carried out the first portion of my duty is obvious from the contents of this book, and, therefore, needs no further comment here, but the others do require a little explanation, if it be only for the novelty of the circumstances.

To begin with, then, the subjects first had to be written about. To Mr. Penn I turned for information on Lignum-vitæ Bearings. Next to Messrs. Maudslay for the practice of Feathering Screw-propellers. Then to Mr. G. B. Rennie for the General Information on Screw-propulsion. Next to Mr. Griffiths for the explanation of the Principles which his Screw-propeller is founded on. To Mr. Charles Barclay for the Geometry of the Feathering Paddle-wheel. To Mr. W. Langdon for the Proportions of Thrust-blocks.

After that I sought information on Twin-screw Propulsion from Capt. T. E. Symonds, R.N., and from Messrs. Dudgeon, the well-known practical advocates of the system. For matters concerning the use of Vanes in Connexion with Screw-propeller Blades, Mr. Arthur Rigg obliged me.

My own contributions now have to be enumerated: they consist of various Articles, such as Preliminary Considerations; Geometry of the Common, and Griffiths' Screw-propellers; A Description of Modern Screw-propellers and Thrust-blocks of all classes; The Principles of Screw-propulsion, and Rules and Tables of the latest and best practice.

The letter-press illustrations and Plates accompanying all of the articles are *bonâ fide practical working drawings*, and as such need no more explanation of their utility.

The third portion of my consideration is very easily explained: it being that I solicited the Articles from the Engineers to be written *by them under their names* with the working drawings of their best practice, and it was *without* exception most courteously granted: indeed, I feel great pride in writing this; for it is really a personal response for the honour that has been paid to me as an author on Marine Engineering subjects; and I here take the opportunity of thanking the Engineers whose names appear in this work for their cheerful appreciation of my professional capabilities.

N. P. BURGH.

78, Waterloo Bridge, London,
June 1st, 1869.

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MODERN SCREW-PROPULSION.

CHAPTER I.

PRELIMINARY CONSIDERATIONS.

BY N. P. BURGH.

THE true value of any scientific work lies in the trustworthy nature of the matter it contains, and in its utility as a guide for all practical purposes. The wants of an engineer in this respect are treatises that deal with facts so clearly, accurately, and concisely that he can put entire trust in them, and apply them with perfect confidence to the requirements of his practice. A great deal also depends on the nature of the information given, and the source from whence it is gathered; every care should be taken by the author that all the facts he quotes are not only genuine, but also the results of practice founded on correct principles, and by explaining those principles he will render the practice of increased value as matters for reference. The book, then, that is best adapted for a standard of reference, is that which is composed of a series of genuine facts, emanating from the best authorities on the subject, and put together in such a way as to be available for use at any moment. It has been the author's aim, therefore, in the present case, to make this work a text-book on the subject of Modern Screw-Propulsion, which may be consulted with confidence as an accurate exposition of the most recent practice in this department of engineering, the information contained in it being gathered not only from his own experience, but also from that of the leading engineering firms of England and Scotland.

The mechanical principles to be studied in connexion with Screw-Propulsion are the basis of various conditional facts which are dependant on the form of the ship propelled; in the main they relate to the density of the water, its natural motion or sea-way, resist-

ance, skin friction of the hull, disturbance of the water, and the nature of the currents therefrom; action of the screw, its pitch, its other proportions and form; positive and negative slip, with other incidental phenomena bearing on the motion of floating bodies. To analyse all these subjects separately is scarcely requisite, as they have such a decided relation to each other that it will be better to allude to them in combination.

To begin, then, what is the cause of the resistance which the hull encounters when in motion afloat? It is the weight of the water displaced by the progressive motion of the hull and its friction against the immersed portion of the ship in motion. It is obvious, also, that the deeper the immersion the greater will be the resistance to the displacing portion of the hull, on account of the greater pressure on the wetted surface of the vessel. The fluid resistance which a ship contends with is of two kinds—that due to the action of waves as when steaming against a head sea, and keel or continuous resistance; the first is of unequal power or force, while the latter is constant. The bottom resistance, however, demands the greatest attention, as on it principally depends the reason why a particular form of the hull determines the speed. Currents also affect the grip of the screw, to which fact reference will hereafter be made. The lines of the hull have also a great influence upon the skin friction or resistance of the water. Fine lines for the fore-and-aft body of the hull are the best for entering and leaving the water displaced, as far as resistance is concerned.

Now, with reference to the continuous resistance, we have the fact fully demonstrated that the deeper the immersion of the body in the fluid the greater the action of contact or resistance. This being certain, may we not conclude also that the *less* the immersion—displacement being also considered—the *less* will be the resistance, thus proving the *advantage* of the *flat-bottom* hulls lately constructed. The question, indeed, becomes a matter of surface and weight, as these mainly determine the amount of skin friction. For example, let two hulls be of the *same* tonnage, the one 10 ft. draught and the other 15, the width of beam being relatively 15 and 10; with the lighter draught, less deeply immersed surface and lower pressure of fluid would be productive of buoyancy; but in the other example, deeper draught, narrower beam, and denser water would uphold the hull.

From these considerations we can readily understand how the narrow and wide hulls are sustained in the water, and can appreciate the well-known fact that a flat-bottomed hull is more rigid in a sea way than the sharper form with the "quick rise" at the side, as it is termed. There will, however, be more skin friction with the flat-bottomed ship, because it has more surface than the narrower beam, although the latter is immersed deeper than the former.

Attention must next be given to the longitudinal form of the hull at the line of flotation. The shape is usually a graceful curve from stem to stern, the width or beam at

the various points determining the fall of the curve towards the centre line. Now, as the ship passes through the water the point of the bow is the first to encounter resistance, and, like a wedge, commences an opening for the following surface to enter, the opening becoming larger in proportion as the wedge is driven farther in. Now, if a wedge is driven into any substance, the portion disturbed will compress the fibre of the material beyond the actual surface in contact; in like manner, also, when the hull is being driven forward it cleaves the water; and the wider the midship section in proportion to the length from it to the bow, the greater will be the friction or resistance.

It is to be deplored that the formula usually employed to ascertain the requisite indicated horse-power, for a hull to be propelled at a given speed, recognises chiefly the midship section immersed in relation to the displacement, whereas it should be constructed in accordance with the form of the forward body also.

To return to the hull's progress through the water: as the ship moves the bow cuts the water, hence the extreme edge of the bow is often termed "cut-water." Now, if we look at this matter in its simplest form, we shall readily understand that to have the least "skin friction" from the bow to the midship section, the form of the hull for that length should be determined by the depth of immersion, width of beam, and the length alluded to; because the separation of the water will be more readily and better accomplished by a definite form than by any other. There should be no assumptions in this matter; the correct "principle" of the question should be recognised, and on that only should practice be founded, if we wish to attain the best results. The action of the forward body of the hull is *pushing*, from which motion it results that the separated water rolls onwards, fold over fold, as may often be seen in the case of river steamers. Some authorities hold the theory that the water immediately surrounding the forward portion of the midship section forms itself into rollers, and that these rollers are pushed for a certain distance parallel with the point of contact, and are then projected at right angles to it. This action is said to occur chiefly with wedge-shaped bows, as with curved bows partaking of the wave-line form; the "rollers" of fluid are merely frictional portions, always intervening between the outside current and the hull. It is, of course, certain that if the rollers in question are "projected," an equivalent amount of power must be in force, and likewise a proportionate amount of resistance and friction involved. Experiments on these matters have been carried out by floating oranges, and the models of various forms of hulls. In one case, with the wedge-shaped bow, the oranges were projected from the point of contact; but the wave-line bow permitted the oranges to be continually in contact with the hull until the midship section was reached. Doubtless, the most exact mode of ascertaining the action of the actual currents of the water would be by experimenting in a miniature *glass* canal, containing clear water, with the models of the hulls of a size proportionate to the amount of fluid usually disturbed in actual practice, so that the

pressure of the fluid should be nearly alike in each instance. The observer could then learn the precise movements imparted to the water by the hull, both at the keel and from that limit to the line of flotation.

Having assumed that the water is pushed aside, fold over fold, as it undoubtedly is, from the bow to the midship section, let us consider next what the after body has to contend against, remembering, as we follow our subject, that it is the *resistance* we are investigating. The hull as it passes through the water divides that element, and therefore disturbs it. When the aft part of the midship section reaches the disturbed water, that portion of the fluid alters its course simultaneously, and instead of being pushed by the hull, is *invited* into a hollow space, whose form is in direct opposition to the bow portion. Presuming that the portion of the hull joining the forward to the aft body is parallel for a certain length, the currents at that locality will proportionately be almost frictionless, due to the natural flow that is permitted. But at the point of deviation, or the commencement of the aft lines, the currents will partake of that alteration in form, and thus the friction will again be increased. As the hull advances the forward currents will run into the channel caused by the after body, and with fine lines aft, the currents in question will follow the hull rather than glide from it. It is certain, however, that only a portion of the forward current conforms directly to the aft lines, the remainder being either parallel with the forward motion of the hull, or forming acute angles with it. Obviously, therefore, as the screw advances it meets with a disturbed series of currents, which can be termed "fore-and-aft water." Now, we must not overlook these latter facts when noticing the probable action of the screw; for we are aware that the screw does *not*, in its present position, revolve in what is termed "solid" water, but rather, as just proved, in a series of currents in a disturbed state. It must not be forgotten that these currents are not only surface *currents*, but also *under* currents, so that nearly the entire area of the circle of the screw's motion may be said to be affected by them, more or less.

Our next determination is the action of the screw in these currents, and the progress of their final combination, which may be termed the forward, aft, and screw currents. The blades of the screw revolve in two kinds of current, the first is the hull surface current, and the second the hull keel current, and the line of division may be taken at the centre of the screw's diameter. We thus have certain evidence that the lower half of the circle of the screw's motion is the more powerful from two natural causes. The first is, the water is more dense below the centre of motion than above it; and the under currents, previously alluded to, *ascend* as the hull leaves them, thus producing the lighter density in question. The second is, that each blade of the screw must *lift* some of the water directly in contact with it as it ascends above the centre line of motion, and unless the screw is *deeply* submerged, a great loss of propelling effect results. Evidence of the correctness of the latter conclusion may be met with constantly where the surface water directly over the screw is

seen to be thrown up *above* the hull's line of flotation. We may, therefore, conclude that the screw *throws back* a certain amount of the water it grasps, and thus an aft *back* current is caused, the production of which absorbs a relative amount of the total power developed, corresponding with the force wasted.

The propeller should in all cases be designed with a strict regard to the nature of these currents, and as those currents are due to the form of the hull below the line of flotation, the immersed lines of the hull must define the correct pitch and area of the blades, their length from the boss to the extremity being in proportion to the depth of the immersion. From the preceding evidence, the delineation of the correct form of the blade, its pitch, and length on the line of keel, must be determined from the duty it has to perform, and the nature of the conditions under which the performance takes place.

We must next notice the relative action of a certain number of blades and their effect. If the propeller has only two blades, each will be alike in effect, alternately, in the two currents alluded to; if three blades are used the greatest effect below the centre line will be when one blade is vertical above the line, in consequence of the area of two blades operating in water of the greatest density. But this unequal effect will, to a certain extent, be counterbalanced by the reverse position of the blades, as, for instance, when the single blade is vertical below the centre line of motion—which, doubtless, produces a more equal effect above and below the line of division of the circle of motion.

Presuming that a four-bladed propeller is in operation, what is the result? Each blade being at right angles with two others, the effect will be as with the two-bladed screw, on account of the relative position of the blades in each case being the same in principle and practice; so that an equal number of blades, with equal positions, produce a relative unequal effect above and below the centre line of motion; whereas an unequal number of blades in any position, although equally distanced, will produce absolute unequal effects.

Having thus far investigated the principles of Single Screw-Propulsion, we now enter on the subject of the Twin system. Now we have already proved, that the screw revolving in *disturbed* water must be subject to a certain loss of power, and, therefore, remembering that the loss of power is due to the disturbed state of the water, may we not safely conclude that two screws, revolving outside or beyond the currents in question, will produce a better effect than the single screw placed in a line with the keel. Next comes the question as to which way each screw should revolve. Some authorities are for an outward motion, or from the keel, and others advocate the opposite. It will be remembered that we have previously stated that "the blades must lift a portion of the fluid." Now, this being proved to be true with twin screws also, two results are certain; viz., first, if the screw turns inwards, or towards the keel, the water will be compressed in that direction, and thus cause a certain amount of extra hull friction. Second, if the screw turns outward, or from the keel, the water

is thrown from the hull and against the volume beyond it, which has no connection with the ships "race." There can, therefore, be but one choice between the two motions; viz., the outward turn for twin screws for a-head propulsion. The author's views on the subject of Twin-Screw-Propulsion are expressed in a paper read before the members of the London Society of Arts in December, 1867, a portion of which is given here:

"Now, with two screws in the place of one, we have a sub-division of the force applied. Taking the midship section of the hull as the transverse area of the resistance, what is the most correct position for the two screws? The answer, in accordance with natural laws, seems to me to be, the centres of the area of the midship-section on each side of the centre line of the hull. For this reason, I think the type of the engine should not settle the distance between the centres of the screw shafts, but rather that the latter distance is due to the form of the hull, so that each screw shall be situated centrally of the area it is propelling. Those who are strong advocates of the advantages of twin-screws for steering purposes, will naturally ignore my opinion, but in so doing will they not sacrifice the correct position for the centres of propulsion? I am confident, however, that the hull will be propelled at a higher speed, when the screws are in the position I have advocated, than otherwise, and the manouvring powers will be but little, if at all, impaired to that if the screws were wider apart.

"To enable you to appreciate the intrinsic value of twin-screw propulsion, I direct your attention to the probable action of the screw when turning from the hull, or towards it. The principle I believe to be thus: The screw is working in disturbed water, caused by the progress of the hull, and the least amount of disturbance added by the motion of the screw the greater propelling effect is certain. When the screw is turning towards the hull the water is dashed against it, and thus additional disturbance and skin friction are caused.

"When I state this, I do not overlook the fact that the screw is advancing; but is not the hull also?—so that the disturbance is a continuation with the passage of the hull. The water, agitated by the inward revolution of the screw, is not only dashed against the hull, but is forced between it and the centre line of the motion of the screw before the screw has left the disturbed water.

"But in the case of the screw turning from the hull, the difference in the effect is evident; the fluid above the centre line of motion is forced from the hull, and, being lighter in density than the volume below, ascends, at an incline to the surface, or line of flotation; it has performed its duty and departs from it, to make room for the new current, without causing any extra skin friction on the hull. It occurs to me that it is simply a matter of gravity or density of the various currents the screw revolves in, and the quicker and easier the screw revolves, the more power it developes. I believe it to be a question of speed, also proportionate to the pitch and depth of immersion, so that, in deducing the

proportions of the screw, all these natural facts should not be overlooked. The surface current nearest the hull must be in contact with it; but those beyond gradually diverge outwards, which is my concluding proof that the propeller should turn outwards also."

The cause of the positive slip of the screw-propeller, is almost obvious, from the preceding remarks relating to the disturbance of the water at the aft end of the hull. Now as the screw revolves in this water, it is conclusive that the blade cannot fully grip the water, if that element is in a separated form, or in streams or currents. It is for this reason that some engineers have placed the screw-propeller *aft* of these body currents, and projected the screw-shaft beyond the rudder post. Other authorities have lowered the screw below the surface current, and thus escape the loss of effect. It will, therefore, be understood that the cause for the positive slip of the screw-propeller, is mainly due to the non-solidity of the water it revolves in, while in other cases the form and proportions of the blades are the cause to a great extent. Negative slip is one of the phenomena that the engineer has yet to explain. At the present time one of the presumptions is that the after body currents are projected upward by the blades of the screw, and thus striking the counter of the hull, impel the vessel forward at a greater speed than that actually performed by the screw. Another idea is, that the natural wave-like motion of the sea, assisted by the motion of the propeller, produces the effect alluded to in this manner. The existence of a following wave explains the fact that any considerable apparent negative slip is always accompanied by waste of motive power, the resistance to the motion of the engine increasing in a greater proportion than its speed is diminished. For amongst the laws of wave-motion are the following: That all forward motion of the particles in a wave is accompanied by an elevation of level, and that the pressure against a body in front of the wave, due to that elevation of level, is exactly equal to the pressure required to impress the forward motion upon the particles of water. Such is the pressure exerted upon the stern of a ship by the wave which follows under her counter, when that wave is undisturbed by the action of the screw. But the screw, by checking or reversing the motion of the particles of water, lowers the level of the crest of the following wave, and diminishes the forward pressure which that wave exerts on the vessel. That diminution of pressure is virtually equivalent to an increase of the ship's resistance: so that the thrust of the screw must be equal not merely to the resistance properly due to the dimensions and figure of the ship, but to that resistance increased by a force equal to the diminution which the action of the screw produces in the pressure exerted on the ship by the following wave. Thus the total thrust of the screw is increased above its effective thrust—that is, above the proper resistance of the ship, in a proportion greater than the proportion in which the speed of the screw is diminished through apparent negative slip, so that the result is an increased expenditure of motive power above what would be required if the screw acted in water not affected by wave-motion. A third conclusion is, that there is a

certain amount of dead water following the slip, impinging on the surface of the after body and the screw. The cause for the impinging being, that the dead water is merely weight converted into force, by being projected or impelled by the forward motion of the currents aft of the hull.

In the face of all these theories, another conclusion has been arrived at, and that is that the entire subject is mythical, consisting of fables formed in the brains of the several theorists who are without practical knowledge of the matter in question. They seem to have taken for granted that the pitch of the screw is in practice as it was intended to be on paper, and they have based their calculations accordingly. Now, it has been argued by some that the present mode of forming the mould for casting the screw—viz., by the loam and sweep-board process—is correct for that purpose only, but that the screw alters in form in cooling. They say, therefore, that the negative slip theory does not recognise this fact, neither do the authorities who advocate the existence of negative slip, therefore their calculations must be wrong, while their whole theory comes to nought for that reason.

The writer's opinions are that "negative slip" is merely apparent, and not therefore actual, although he has proved often that there has been an aft current, with a forward motion exceeding that of the hull, with ships and propellers of certain proportions. This was known by lowering a piece of light wood by a string into the well-hole of the screw, where it was seen that the wood was driven forward until the string became "taut," and on releasing the deck end of the string it "ran" through the hand. The result of the trial also showed apparent "negative slip;" yet, with all this evidence, an acquaintance with natural laws tends to raise the doubt of the existence of the fact that any propeller, when revolving at its greatest speed, *can* be *dragged* by the hull, which owes its forward motion to the action of that propeller only.

All these and other matters which have been alluded to will receive more attention in their proper places, accompanied with results, the present chapter being merely a brief preliminary sketch of certain principles on which screw propulsion is based.

CHAPTER II.

INTRODUCTION.

BY G. B. RENNIE, ESQ., M.I.C.E.

AT the request of Mr. N. P. Burgh, I agreed to write a short introduction to a new work he was about to write on Modern Screw-Propulsion. It was with some reluctance I acceded to his request; but, on consideration of the great pains and trouble that gentleman has bestowed on his work on Marine Engineering, collecting some of the best examples of modern marine engines, in having them illustrated in the most clear and correct manner, as well as combining in the body of the work numerous wood-cuts of details of construction peculiar to different makers, I felt sure the main importance of his publication would depend more on the excellence of its illustrations than the few remarks which I might have to offer on the subject. After all, the best and most useful information for an engineer, is that which relates to the different views and mode of construction carried out by the prominent manufacturing engineers, who have devoted the best part of their lives and labours in perfecting an especial branch of mechanical study. Those, therefore, who wish for information on the various forms and construction, of the screw-propeller, I would recommend rather to examine, and carefully to compare, the Drawings of the Screws in this work, and results of different vessels, more particularly those of the Admiralty, than to look for anything that is new in this introductory account of the history, various forms, and adaptations of the screw-propeller, which I have contributed to the present work.

OUTLINE OF THE HISTORY OF THE SCREW-PROPELLER IN ENGLAND.

Since the introduction of the screw-propeller, the use of steam, as a motive power, has attained a more rapid extension for sea navigation, than would ever have taken place, had

it been limited to the paddle-wheel. The general form of a ship, with its masts and sails, requires less modification for the screw than the paddle-wheel, and retains all its advantages for sailing purposes. In the case of the mail steamers, where it is necessary to steam direct from port to port, and sail only when there is a strong and favourable wind, the screw is found to be the most economical way of using the steaming power, more especially in long voyages, where the draft and immersion of the ship varies considerably, at starting, after coaling, on the voyage, and on arrival in port. The paddle-wheels are for a great part of the voyage either too deeply or not sufficiently immersed, whereas, in the screw propeller, the greater immersion gives the screw a better hold of the water, thus compensating, in a great measure, for the increase of displacement in the ship without materially affecting the steaming speed.

The first practical application of the screw-propeller seems to be due to Shorter—at the commencement of the present century—who made numerous experiments, and even succeeded in propelling the *Superb* line-of-battle ship about two miles an hour; the conclusion he arrived at was, that a single blade gave the best results. Some twenty years later, Brown applied his gas vacuum-engine to propelling a two-bladed propeller attached to a shaft working through a stuffing-box; the best result which he seems to have obtained was a speed of seven miles per hour with 12-horse power. In 1836, Mr. Francis Pettit Smith obtained his patent for a screw propeller, and applied it to a small boat 34 ft. long, 6 ft. 6 in. beam, and 4 ft. draft. The engine consisted of a high-pressure cylinder, 6 in. diameter and 15 in. stroke, which worked a screw 2 ft. diameter, and 2 ft. 5 in. pitch; this was placed in the dead wood at the stern, and not in the bow, as in Brown's boat, by which a somewhat similar speed was obtained; but its power was subsequently shewn by towing the *Great Western* steamship into the East India Docks. This boat was so far successful as to induce Messrs. Wright and Co.—bankers—to embark in the speculation of building a vessel on the same principle, from 200 to 300 tons, and 80-horse power; but no engineering firm seemed willing to undertake such a doubtful experiment, until at last the late Mr. George Rennie was requested to examine the subject; and he, after giving it his careful consideration, came to the conclusion that the principle was not only practicable, but would lead to most important results. It was arranged that the firm of G. and J. Rennie should construct the machinery, and Mr. Wimhurst the vessel, which was to be of wood. The engines were direct acting, as for paddle-wheels, but placed longitudinally in the vessel, instead of transversely. The screw-shaft was to be driven by means of gearing, in the proportion of 25 revolutions of engine to 133·3 of screw-shaft. The screw-propeller was to be placed in a space cut out of the dead wood, just before the rudder-post, and the shafting to pass through the stuffing-box. The propeller recommended by Mr. Smith was to be a complete turn of a single-threaded screw, but a double-threaded one was afterwards adopted. In *Herapath's Journal* of June, 1839, the

editor remarks that the "expectation of the success of this experiment was at a very low ebb." The dimensions of the vessel, as constructed, were as follows:

Length from stem to stern	105 feet.
Extreme width	$20\frac{3}{10}$ "
Depth of hold	$12\frac{5}{10}$ "
Burthen in tons	230 "
Length of engine and boiler space	39 "

The vessel was built of fir and rigged as a three-masted schooner. Mr. Rennie writes: "The lines fore and aft are beautifully run, and the vessel is well calculated to go through the water, both with steam and under sail." The engines consisted of two cylinders each 36 in. in diameter and 3 ft. stroke. "The wheel work," Mr. Rennie writes, "consisting of two cogged wheels and two pinions, is placed in a strong iron frame, independent of the vessel. The shaft which drives the propeller passes from the lowermost pinion under the cabin-floor and through a water-tight stuffing-box in the inner stern-post to the propeller or screw. The screw is made of plates of iron, fastened to arms of wrought iron, keyed upon a wrought-iron shaft, and when the engine is at work, makes $5\frac{1}{3}$ turns for ever complete revolution of the crank shaft. The weight of engines, boiler, chimney, coal-boxes, driving machinery, and propeller was 64 tons 8 cwt." The first trial of the *Archimedes* took place in Barking Creek on the 30th of April, 1839; the speed was estimated at $8\frac{1}{2}$ miles. The vessel was found to answer the helm and obey all the necessary movements, such as advancing, stopping, and backing, as well as any steamer on the usual principle.

On the 2nd of May, she left her moorings off the Brunswick Dock, and reached Gravesend, a distance of 20 miles in one hour and forty-five minutes, and the next day left for the Nore and Sheerness, where she exhibited her steering qualities by going in and out amongst the shipping. Admiral Otway, who commanded the fleet, came on board and steered himself. At the trial, the dimensions of the screw were 6 ft. diameter and 7 ft. 6 in. pitch, this was substituted at Ramsgate for one of 7 ft. diameter and 8 ft. pitch, with the result of an increase of speed. She then returned to London, having been considered, by all interested in her, a complete success, and on the 18th of the same month left for Portsmouth, where she excited much interest. Mr. Rennie concludes his letter by saying, on her arrival at Portsmouth, she was "visited by all the naval authorities, both scientific and unscientific, and there appeared to prevail but one opinion as to the efficiency of the principle for naval warfare. By this arrangement the engines are completely protected from shot by the coal-boxes on either side, whilst the propeller, from being wholly immersed under water, is out of reach of shot. The funnel is the most vulnerable point, but it might easily be replaced, in case of accident, by having a spare funnel below, constructed on the telescopic principle." The screw-propeller was made to connect and disconnect for sailing.

The interest excited by the success of the voyages of the *Archimedes* induced the Admiralty to make some comparative trials with a paddle-wheel steamer. Captain E. Chappell, R.N., and Mr. Thomas Lloyde, Engineer to the Navy, were directed to superintend them, and they proceeded to Dover, in May, 1840—just one year after the *Archimedes* left the Thames for that purpose—the paddle-wheel vessel selected was the *Widgeon*, the fastest steam packet on the Dover station. The following were their respective dimensions :

	Tons.	Inches.	Stroke.	Mean draft of water.
Widgeon	162	39	3·1	7·3
Archimedes . . .	237	36	3	9·4

So that the *Widgeon* had 10-horse power more and 75 tons less burthen than the *Archimedes*.

On the first trial, a distance of 19 miles, the engines of the *Archimedes* made 27 revolutions per min., speed $8\frac{1}{2}$ knots per hour, but the *Widgeon* performed the distance in 6 min. less time, and on the return voyage 10 min. less time. The third run the *Archimedes* was only 3 min. less time, making 27 strokes per minute, and performed the distance in 2 hours $9\frac{1}{2}$ min.; on the fifth trial, both vessels had sails set, the *Archimedes* beat the *Widgeon* by 9 min., making 27 to 28 revolutions, and 9 to $9\frac{1}{2}$ knots per hour. Thus the *Archimedes* made the voyage from Dover to Calais in less time than it had been performed by any of Her Majesty's Packets, running from port to port in 2 hours and 1 min., and returning in 1 hour $53\frac{1}{2}$ min. The *Archimedes* continued to perform her work most satisfactory until one morning, before starting, the engineer in charge had omitted to slacken the funnel stays, which caused the crown of the boiler to collapse, in consequence of the expansion in the boiler due to getting up the steam; unfortunately one man was killed and others severely scalded. Efforts were made at the inquest to prove that the accident was entirely due to the designs for the machinery made by Mr. Rennie, until the late Mr. Joshua Field—of Maudslay and Field—most handsomely came forward, and gave his evidence so conclusively in Mr. Rennie's favour, that the case proceeded no further. However, this unfortunate accident, although in no way connected with the design or construction of the machinery or boilers, had for some time a prejudicial effect against the firm of Rennie in the construction of marine engines, and they did not, in consequence, reap that benefit from the introduction of the screw-propeller which they were entitled to. The Admiralty commenced the *Rattler* screw-ship, but the order for the machinery was confided to Messrs. Maudslay and Field, in September, 1841. This vessel was not tried until June 27, 1844. when she obtained a speed of 10·074 knots. In the early part of the year 1840 Messrs. Rennie undertook the construction of a rotary engine, designed by Galloway, to propel a screw vessel built by Messrs. Ditchburn and Mare, called the *Mermaid*. However, it was found difficult to make the joints of the engine tight; and from the failure of the bank of Wright and Co., in November, 1840, nothing further was done with the screw-propeller until Mr. Rennie and his brother, Sir John, induced the Admiralty, with great difficulty, through

Sir George Cockburn, to purchase of them the *Mermaid* on the condition a speed of twelve miles was attained on trial. The agreement was made on the 7th of March, 1842. The speed proposed was greater than any steamer then in the navy could perform, and the payment was to be contingent on that speed being realised. The trial took place over the measured mile, on the 15th of May, 1843. The mean speed obtained of 6 runs was 12·142 miles. The *Mermaid's* propeller was of cast iron, and was moulded in loam without a model, by means of iron tem-plates cut to the required curve, which was formed from a solid cone revolving on its axis, during the perpendicular descent of a tracer.

The length of the *Mermaid*, or *Dwarf*, was .	130 feet.
Beam	16 ft. 6 in.
Draft	5 ,, 6 ,,

This trial was considered so satisfactory, that the Admiralty completed the purchase, and thus the *Mermaid*, afterwards named the *Dwarf*, was the first screw vessel introduced into Her Majesty's Navy. The trials of the *Dwarf* and *Rattler* conclusively established the advantages, in naval warfare, of the screw over the paddle-wheel for propelling ships.

The study of the action of the screw, and its position in the dead wood at the stern, led to an improvement in the lines of vessels by giving them a finer run, which was afterwards adopted in every class of vessel, sailing as well as steam ships. The next step was to get a class of engine especially adapted to work directly on the screw shaft, without the intervention of gearing, and to make a greater number of revolutions per minute than paddle-wheel engines. The Board of Admiralty, at the suggestion of the Harbour Defence Commission, determined to take advantage of this system of propulsion by constructing some sixteen ships, especially for defence of the ports; eight of which were called *block ships*, and the other eight line-of-battle ships and frigates. The only conditions stipulated were, that the machinery should be placed below the water line. Those made by Messrs. Maudslay and Sons, Messrs. Boulton and Watt, Messrs. Seaward, Messrs. Penn and Sons, and Messrs. Rennie, were direct-action horizontal engines, with a speed varying from 45 to 60 revolutions per minute. Messrs. Miller and Ravenhill, were also at this time constructing a direct action engine for the *Amphion*, after Count Rosen's plan, ordered the year previously. These engines had a stroke of 4 ft. and to make 48 revolutions per minute.

In the merchant service, the *Great Britain* of 3400 tons, then the largest ship and wonder of the age, designed as an ocean steamship by Mr. Brunel, played a most important part in furthering the introduction of screw-propulsion; but the errors of the construction of the machinery and the engines were prejudicial to the system being considered favourably for full powered ships, and screw-propellers were only held to be advantageous as an auxiliary in calms and favourable winds. However, further experience

has proved the screw to be a more useful propeller than the paddle-wheel, whether in the calm seas of the Mediterranean, or in the high waves of the Atlantic, and nearly all large steamers for ocean mail service are constructed for screw-propulsion, and many instances might be cited, both in this country and in France, where it has been found worth while to alter, comparatively speaking, new paddle-wheel ships into screws, at a cost not much under a fourth, or even a third, of the cost of a vessel when new.

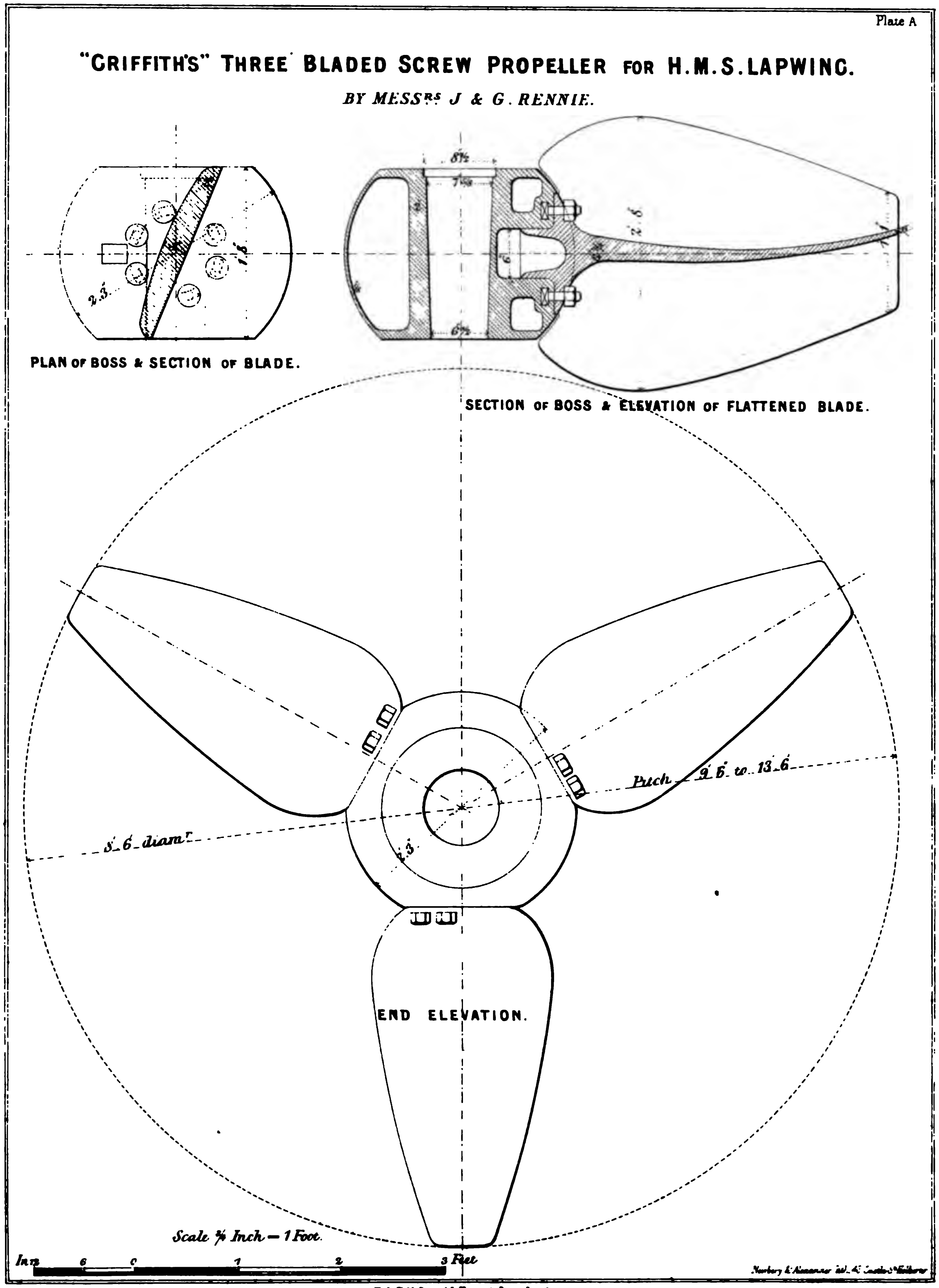
After some years' experiments with a single screw, a system of two screws instead of one came into practice with the idea that this application of the screw in certain cases was more advantageous; so that a few remarks on the double screws will be desirable.

DOUBLE SCREWS.

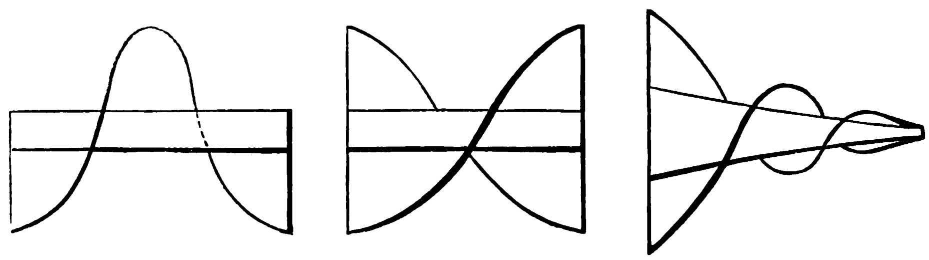
The original advocate of this system was Captain Carpenter, R.N., who, in 1840, had a small model made and tried on the Serpentine, with such success, that Mr. Rennie constructed a small iron vessel on this principle in 1852 for Said Pasha, for the purpose of navigating the canals in Egypt. This boat had only two feet draft of water, and was propelled by two screws, each worked by a separate Disc engine. Several others on the same system were constructed, and also ten iron gunboats, of 20-horse power each, were made by Messrs. Rennie for the Indian Government in 1857. Each screw in these cases was worked by a single horizontal cylinder piston-rod engine; others, again, on a larger scale, and similar in other respects to the above, were made and sent out to the Phillipine Islands for the Spanish Government. These vessels had only 2 ft. 4 in. draft of water, fitted with engines of 20 and 30-horse power, and under these conditions a single screw-propeller could hardly be expected to give a good result: hence the application of two screws for augmenting the surface of propulsion. It is thought by some that a higher degree of speed may be obtained in vessels of deep draft by adopting this system; but the limit of advantage is evidently to such vessels only where the draft of water will not admit of a single screw of sufficient dimensions to give the proper resistance for propulsion. However, for particular purposes for the manouvring of ships of war, two screws may be found more serviceable.

ON THE DIFFERENT FORMS OF THE SCREW-PROPELLER IN USE.

The screw first proposed by Mr. Smith, for the *Archimedes*, was that of the trace of a single thread wound around a cylinder, which was afterwards superseded by another, with a double-thread, each thread having half a turn. Mr. Rennie was led, from considering the action of a fish's tail on the water, to design one of a form traced out by one or more threads wound around a cone instead of a cylinder. A series of experiments were made with this propeller, and found to answer the expectation of its designer. The three forms are shewn in the next page.



E & F N Spon, 48, Charing Cross, London



It would be quite impossible to describe here all the various forms suggested by inventors, but a very complete and interesting collection may be found at the Patent Office, or in "The Screw-Propeller," by Bourne. The screw adopted by the Admiralty for some time was a section of two-threaded screw, commonly known as the Admiralty two-bladed screw, the length being $\frac{1}{6}$ of the pitch. These proportions were arrived at after a series of experiments. For speed in smooth water it is very questionable whether there is a more efficient propeller, but for other reasons, such as vibration and uniform action in a sea-way, other forms are found preferable. Some few years ago screws, with movable blades for regulating the pitch by means of gear worked from the deck, and known as the differential, or feathering screw, were considered of great importance, as the pitch of screws might be varied to the wishes of the captain and engineer, according to whether the wind was favourable or adverse, and thus adapt the speed of the engines, so that the greatest power might be developed under all circumstances. That made on the patent of Mr. Joseph Maudslay was the most successful of this kind of screw; however, the extra complication and the excessive wear in the movable parts have led to their use being limited, and it is now found most advisable merely to bolt or key the blades at a determined pitch, which can only be modified by the vessel either going into dock or the screw raised on deck with lifting gear. Mr. Griffiths's screw is made on this plan. The boss or centre on which the blades are bolted is made from $\frac{1}{4}$ to $\frac{1}{3}$ the entire diameter of the screw, and in a spherical form. Mr. Griffiths thinks that this form gives less obstruction to propelling the vessel than when the blades are carried nearer to the centre, and where the angle of the blades is very acute with the line of motion. He also advocates diminution on the breadth of the blades towards the extremity, and an increase at the base, which is found to lessen the vibration. The late Mr. George Rennie had previously entertained this idea, as may be seen from the form of blade in his conoidal propeller; but Mr. Griffiths has taken advantage of later experiments, from which it was found that a small part of the convolution of a screw was more effective than a complete turn. Mr. Griffiths's screw has had such favourable results, that it is now very generally adopted both in Her Majesty's ships as well as in the Mercantile Marine, with the modification of curving the blades at the outer extremities slightly forward, as, for example, may be seen in the screw of Her Majesty's ship *Lapwing*.

Diagram of a screw-propeller with straight blades, showing the line of current from the blades.

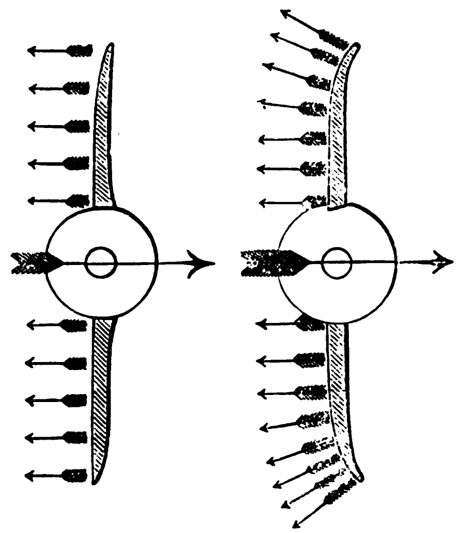


Diagram of a screw-propeller with curved blades, showing the line of current from the blades.

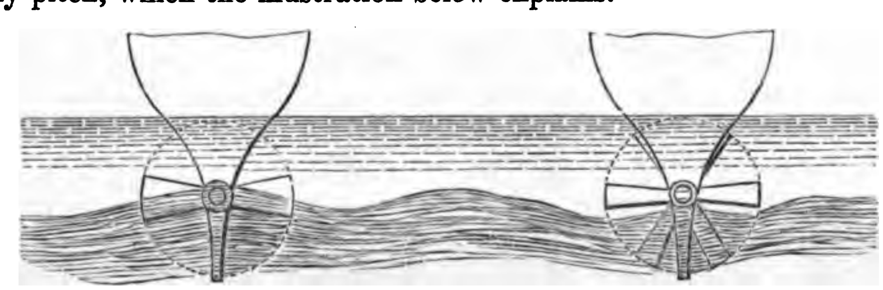
Referring next to the effect of the sphere as regards speed, experiments made on board the *Conflict*, with a common Admiralty screw compared to the same screw with a large sphere fixed to the centre, gave the following result:

	Speed in knots.	Displacement in tons.	Horse power—actual.
Common screw . . .	9·425 ...	1740 ...	784
Ditto, with sphere . .	9·424 ...	1752 ...	814

The experiments on the *Fairy* shows a very similar result:

	Speed in knots.	Horse power—actual.	Positive Slip.
Common	13·229 ...	406 ...	17·15
Griffith's	13.27 ...	410 ...	23·26

The pitch of the latter was 4 in. greater, but the speed was practically the same as with the decreased pitch in the common screw, the difference being in a diminished slip with less pitch. The form of propeller much used in the French navy, as well as in the French mail steamers, has six narrow blades. Many trials in the French navy, for comparison, have been made with it and the Admiralty two-bladed screw, and, although very little was found to be gained in speed, the vibration was sensibly diminished. The Imperial Messagerie have also made their experiments during long voyages, and found the above results hold good in fine weather only; but in a heavy sea and strong head wind, the surface of the six blades being more distributed throughout the circumference than the two blades; there is always more or less of the former screw under the water, however much the vessel may pitch, which the illustration below explains.



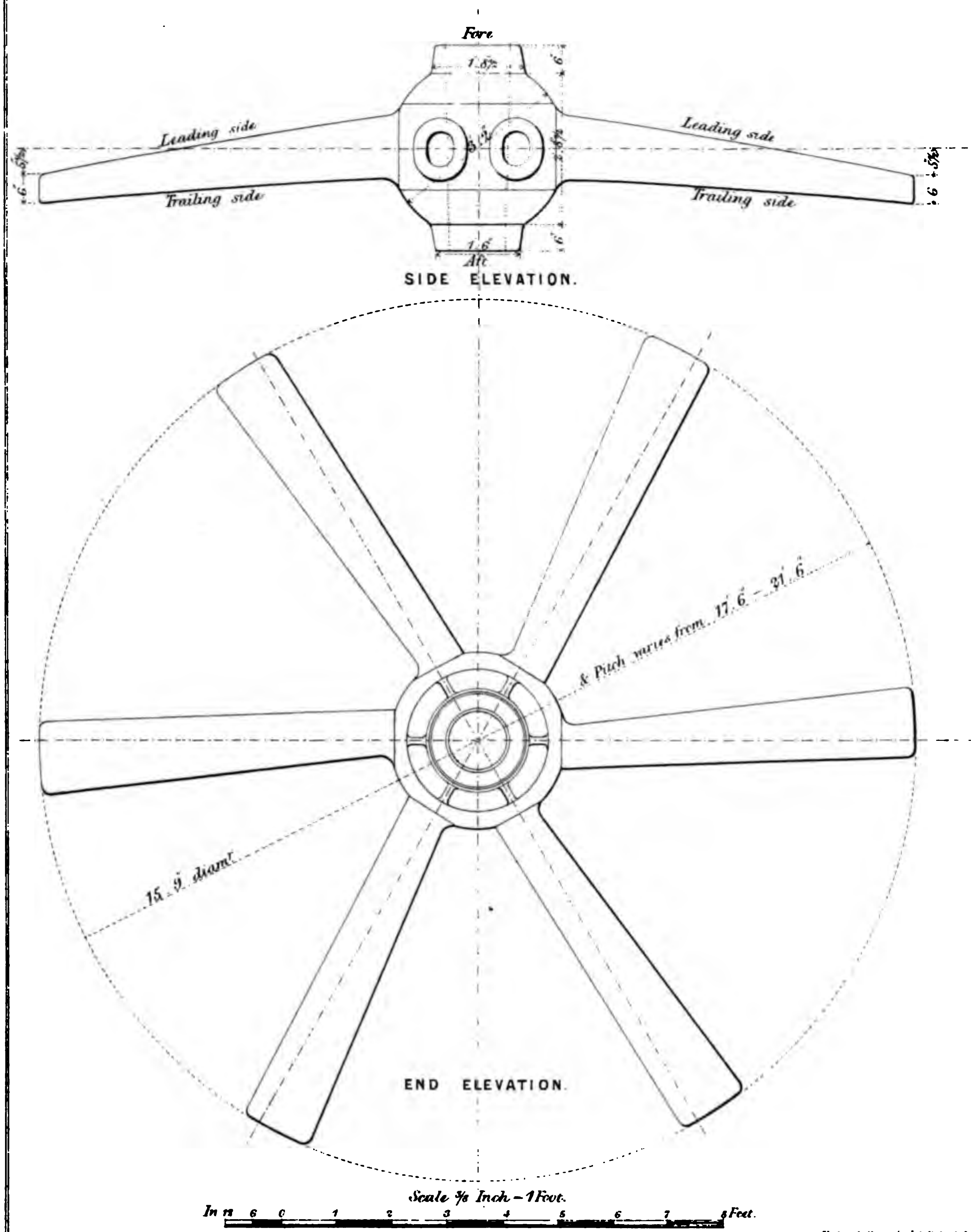
Ordinary water line.

Water line when pitching.

Plate 8

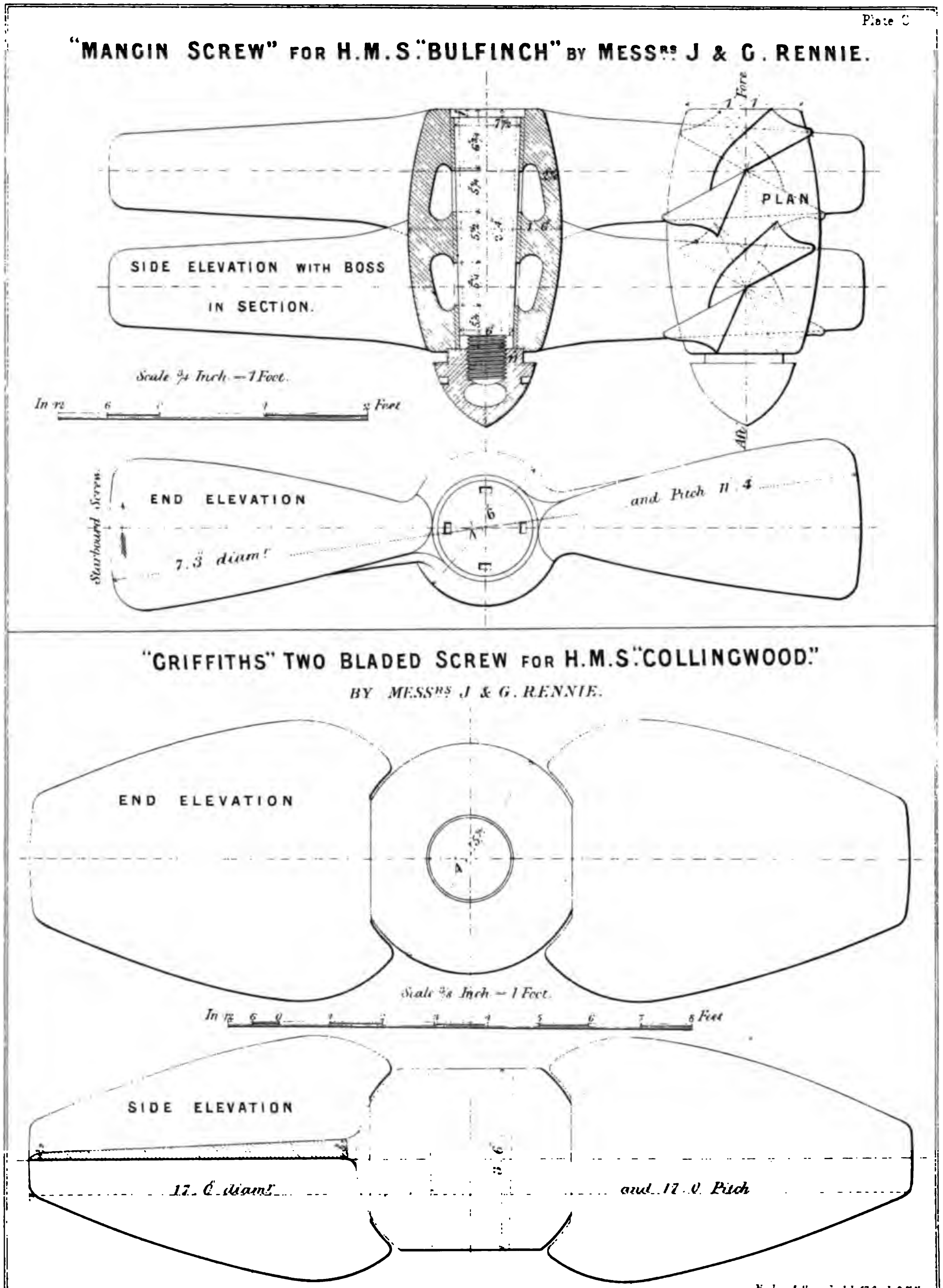
SIX BLADED SCREW PROPELLER FOR EGYPTIAN GOVT. STEAMER "CHARKIEH"

BY MESSRS. J & G. RENNIE.



Newbery & Alexander, Lith. 6, Castle St. Holborn

E. & F. N. Spon, 48, Charing Cross, London



F & F N. Spon. 48 Charing Cross London

It is considered that as the blades are more numerous and less in size, the action is more uniform, and that there is more equality of resistance owing to a portion of the surface of the screw being in deeper water than in a two-bladed one, where the resistance continually varies throughout the revolution, and gives rise to a certain amount of vibration. The accompanying drawing is that of a screw-propeller of six blades, made on the above principle for the *Charkieh.* These blades were keyed on for the purpose of varying the pitch, and made of wrought iron in order to combine strength with a thin and narrow blade. Particulars of this vessel and her engines may be seen in "Burgh's Modern Marine Engineering."

The following comparison of a three-bladed and a six-bladed propeller is extracted from the log of the steam ship *Charkieh,* to show the relative speed of the two :

Kind of propeller.	Steam in boilers.	Revolutions	Coals consumed per hour.			Mean speed in knots per hour.
	lbs.	per minute.	cwts.	qrs.	lbs.	knots.
Six-bladed screw from Malta to Alexandria, after being docked, May 17th, 1866	18·8	60·4	33	3	15	10·65
Three-bladed screw from Venice to Alexandria, after being docked, July 27th, 1867	19·2	58·9	34	0	9	10·69

So that, practically speaking, there is very little difference as regards speed or economy of fuel in using either the six or the three-bladed propeller in smooth weather, but the vibration in the former was considerably less.

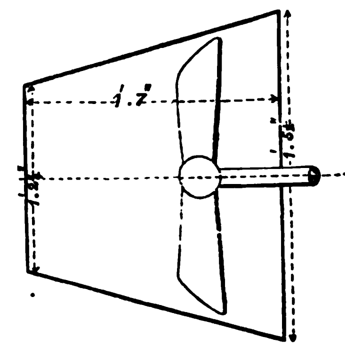
Trials of comparison, made by order of the Admiralty, with a two, a four, and a six-bladed propeller, on board the *Emerald,* show the following results respectively, (after correction for the reduction of tonnage and horse power to the same in all cases) :

11·49 knots—11·79 knots—and 11·87 knots.

A form of screw much used in the French navy, and in some of Her Majesty's ships, is that proposed by M. Mangin. It consists of two narrow blades, one placed immediately behind the other, each of a similar and uniform pitch. That made for the *Bullfinch* is an illustration of this construction, as shown by the plate.

Another form is the four-bladed French screw, with the pitch of one-half of the blade in excess of that of the other half. This screw, as used in the English navy, almost always shows an *apparent negative slip.*

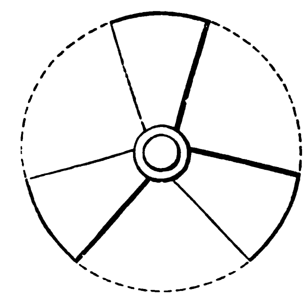
The following particulars, taken from some experiments to determine the resistance of different forms of screw-propellers, by the late George Rennie, give some interesting information on the subject: the results of these experiments, made on differently formed propellers, for the purpose of ascertaining, first, the effect of screw-propellers when confined in tubes of a conical form; secondly, the effects of the form of propellers working alone and not in tubes, are on the next page.



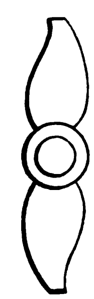
The *common two-bladed screw,* 13 in. diameter, pitch 20 in., 600 revolutions per minute, when working in a depth of 12 in. above top of screw, gave a pressure

of 69 lb. in a conical tube $\left\{\begin{array}{l}\text{1 ft. } 5\tfrac{1}{2} \text{ in. diameter, large end.}\\ \text{1 ,, } 2\tfrac{3}{4} \text{ ,, ,, small end.}\\ \text{1 ,, 7 ,, in length.}\end{array}\right.$

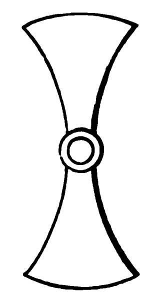
The *same two-bladed screw,* when immersed and working in a depth of 12 in. above top of screw, gave a pressure of 144 lb., or more than double what it gave when confined by the tube.



Without working in a tube.—The effect produced by a three-bladed screw-propeller of nearly similar diameter 13½ in., and pitch 20 in., area of circle 1 square foot as the two-bladed screw, moving with the same velocity of 600 revolutions per minute, and immersion of 12 in. above the level of the screw without a tube, amounted to a pressure of 157 lb.



Without working in a tube.—The effect produced by a two-bladed screw-propeller, 13½ in. diameter, and 20 in. pitch, area of circle, 1 square foot, but tapered at the outer extremities of the blades to a parabolical form, as in the figure, was :—137 lb.



Without working in a tube.—The effect produced by a two-bladed screw-propeller, similar to the common screw, diameter 13½ in., and 20 in. pitch, area 1 square foot, but having a portion of the interior of its blades cut away in hollow curves, as shown, was 176 lb.

ON THE ACTION AND EFFICIENCY OF THE SCREW-PROPELLER.

The main object of every propeller is to utilise the power in such a manner that the greatest possible speed may be obtained with the least possible power; also that its position may be such, so as not to inconvenience the ordinary working or manœuvring of the ship; and that its effect may be produced without any disagreeable sensation to those on board.

The *screw-propeller*, if due attention be paid to its action, is capable of fulfilling these conditions in a high degree: first of all, it is necessary that it have sufficient surface in order to give the required resistance; and secondly, that this surface be so applied as to give the *least slip*, *the least friction*, and *the least vibration.*

The slip will vary with the angle of the propeller, the velocity of the blades through the water, and the depth of their immersion.

The friction will depend on the smoothness and equality of the surface of the blades, and their velocity through the water.

The vibration will be influenced by the form of the blades, and the uniformity of their resistance throughout their surface.

THE SLIP OF THE SCREW-PROPELLER.

The *true slip* of a screw-propeller may be represented by the velocity of the current of water pushed back by the screw blades; when the propeller is close to the stern of the ship, it partly arrests the flow of the water which follows the ship, and thus lessens the hydrostatic pressure which urges the ship forwards; generally the area of the current caused by the ship exceeds the area of the current forced back in an opposite direction by the screw; and the alteration in the resistance so produced constitues a difference between the *total thrust* and the *effective thrust*, this difference, or loss of thrust, being proportional to the difference between the *real* and *apparent slip.*

It will be observed from this, that a screw working in the *onward* current may indicate a result such, that when this current exceeds in velocity that of the opposite current caused by the screw, there will be an *apparent negative slip;* or, in other words, the ship will appear to go faster through the water than the revolutions of the screw multiplied by the pitch, indicate.

The current caused by the onward motion of the ship has a velocity at the stern equal to that of the ship itself, and diminishes in proportion to the extent of the area of water forming the current, so that the greater the distance the particles of water are from the ship, the less is their velocity. From this it is evident that a screw, which works close to the stern, is more affected by the current than one working some little distance from it, and will show a greater *apparent slip*, as its distance from the stern increases, until the *apparent slip* becomes equal to the *real slip.*

All screws have a *real positive slip*, but the coarser the pitch the greater is the slip. With screws of a coarse pitch, the *following current* usually reduces only the amount of *apparent positive slip;* but with fine pitched screws, where the *real positive slip* is small, then a negative slip will sometimes be apparent; when either of these occur, it may be safely inferred that the screw is not in its most advantageous place.

Mr. Froude gives the results of some experiments made by him in a small boat 3 ft. in length, which confirm the preceding views. He found that by the removal of the

propeller from its ordinary position to just abaft of the after stern-post, a larger increase both of speed and distance run over for a given power and number of revolutions was produced, and that each succeeding position farther aft was attended with a further increase of speed, although towards the final position of maximum advantage the rate of increase was less, and by comparison with the result obtained, when the propeller occupied its ordinary position with that of its position of maximum advantage, the speed increased from 0·98 to 1·40 knots per hour.

In the case of double screws working under the quarter, the increase of advantage is not quite so apparent, as a great part of the screw works farther from the ship's side, and therefore is not so much affected by the current; however, several cases might be cited in which an increased result is gained by placing the screws well aft, as in the following example, which gives the result of the trials of three different boats of the same dimensions and weighted to the same displacement, with the screws in different positions.

There was but little difference in the indicated horse-power of the engines at the time of trial; but in order to make a more ready comparison the comparative speeds have been calculated, supposing the same power to have been obtained in all cases. The accompanying plates shows the relative positions.

Distance of centre line of screw from stern-post. ft.	in.	Speed of ships in knots.	Slip per cent.	No. of boat.
0	4½	8·117	10·5	1
0	8½	8·003	28·29	2
1	0½	7·642	37·64	3

The screw-propellers were of similar construction, but the areas slightly differed. Thus:

	(No. 1)	(No. 2)	(No. 3)
Areas of blades	254 sq. in.	286 sq. in.	296 sq. in.
Pitch	3 ft.	3 ft. 6½ in.	3 ft. 9 in.

The following shows the advantage of working screw-propellers in double-screw ships outwards instead of inwards, as in Her Majesty's ship *Vixen*, given below.

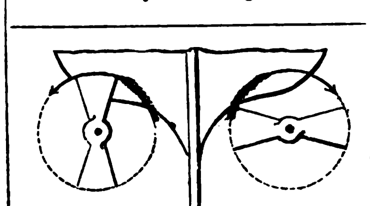
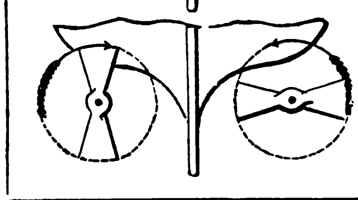
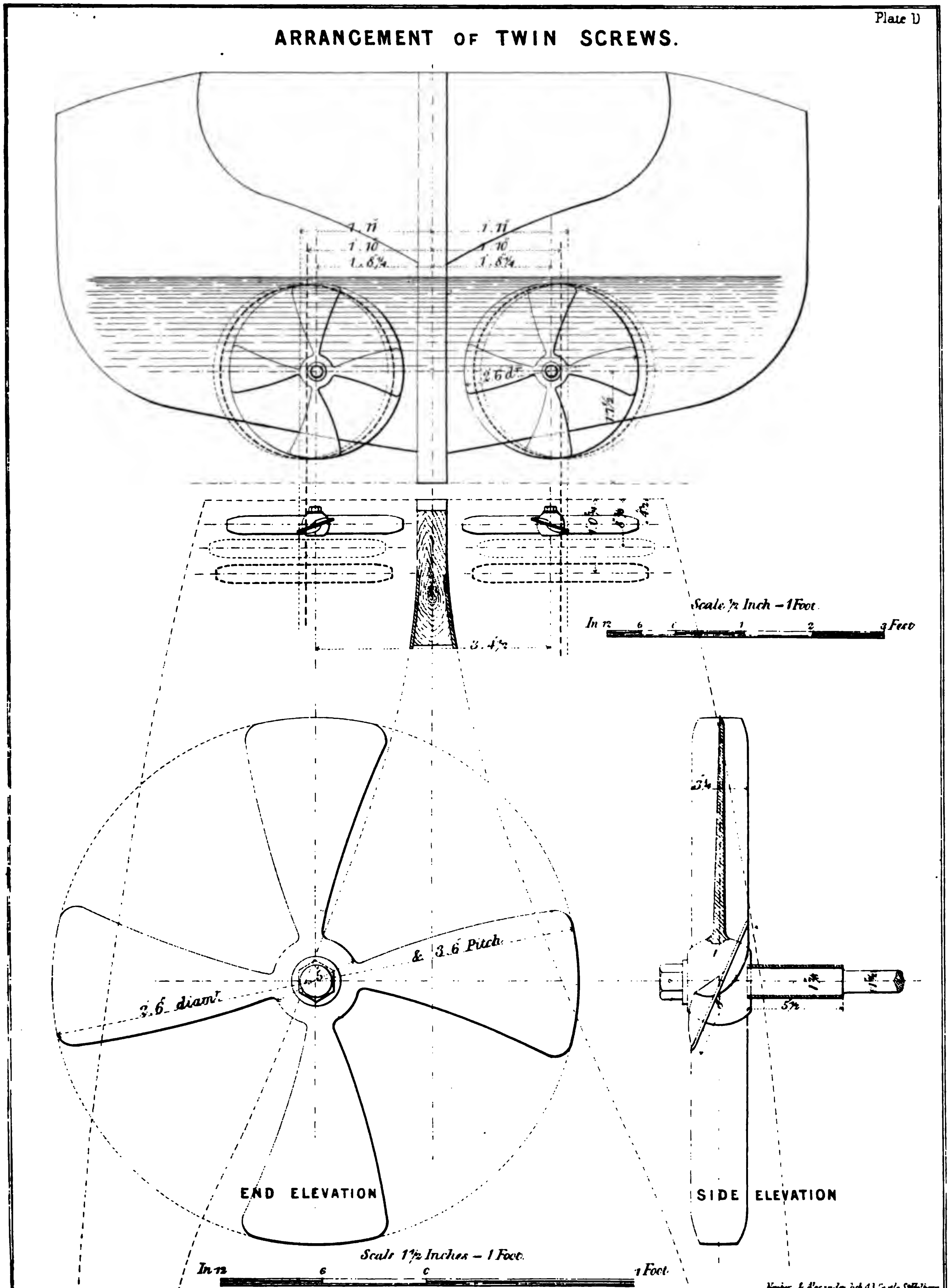
Way of working.	Mean indicated horse-power.	Mean revolutions per minute.	Mean speed in knots.
	751	111⅔	9·216
	766	114¾	9·004

Plate D



E & F N Spon, 48 Charing Cross, London

The plan of working screws *outwards* has been adopted by Messrs. Rennie for some years.

THE EFFECT OF THE ANGLE AND THE DEPTH OF IMMERSION OF SCREW-PROPELLER BLADES.

The action of a screw-propeller is that of one or more blades forming portions of a screw, which act obliquely on the water, and rotate about a central axis.

As is well known, the resistance to a body passing through water acts perpendicularly to its surface, and therefore the more the propelling blade is at a right angle to the line of motion of the vessel, the greater will be the proportion of thrust in that direction; but since the principle of a screw is that of an inclined plane revolving about a centre—the angles of which vary according to the diameter, there must of necessity be some angle in the blades, and consequently a certain amount of lateral resistance, which will be proportional to the angle of the blade; this is usually counteracted or balanced by the successive positions of the blade as it rotates round its axis, and is thus not apparent in the ship's motion. However, this is not always the case, for, since the resistance materially increases according to the depth of immersion, the resistance on the blade in its lower position exceeds that in its upper position, and a sensible lateral motion is the result. The greater the diameter and the greater the angle of the blade the more is the motion apparent, and may account for the fact that some screw steamers are said to carry a port or starboard helm. The late Mr. Joseph Maudslay frequently illustrated the effect of this difference in resistance in a very striking manner. He had his yacht fitted with one of his feathering propellers, with the blades fixed fore and aft in a line with the keel, and when the engines were set in motion, the vessel very soon turned round on its centre. Double-screw steamers have been made in America with very large propellers, a considerable portion of them being out of water, in some cases amounting to half their diameter; the lateral motion is balanced by each propeller being made to revolve in an opposite direction; and since the limit of a screw-propeller's diameter is the draught of water of the ship, a much larger propeller, with proportionately smaller angles, may be obtained by this arrangement.

The following Table shows the difference in resistance of a screw working at different depths, taken from some experiments made in 1856, by the late George Rennie, in the River Thames.

The propeller used was a brass two-bladed Admiralty screw; diameter 1 ft. 9 in. area of circle 346½ square inches.

Revolutions at all depths—558 per minute.

No. of experiments.	Height of water above top of screw.	Weight to balance thrust of screw.	No. of experiments.	Height of water above top of screw.	Weight to balance thrust of screw.
	ft. in.	lbs.		ft. in.	lbs.
1	Water level . 0 0	49	8	Above . . 2 6	364
2	Above . . . 0 3	50	9	" . . 3 0	369
3	" . . 0 6	196	10	" . . 3 6	371
4	" . . 0 9	224	11	" . . 4 0	385
5	" . . 1 0	252	12	" . . 4 6	399
6	" . . 1 6	280	13	" . . 5 0	405
7	" . . 2 0	343			

The ordinates of the above thrusts are approximately represented by a parabolic curve.

It was proposed by Mr. Arthur Rigg, about a year or two ago, to increase the efficiency of screw-propellers by fixing blades of a screw-propeller to the stern-post abaft the working screw, in order that the current pushed back by reaction against these blades might assist in thrusting the ship forwards; but they appear to have the effect of merely deflecting the current in the opposite direction, without any beneficial results, except in the case of narrow channels, such as canals, where Mr. Rigg affirms there is an additional thrust, as shown in the trials given below.

The following experiments were made on a steam pinnace belonging to Mr. G. B. Rennie, in order to test the efficiency of Mr. Arthur Rigg's "*deflector vanes*," when fixed on the after stern-post.

Six runs with and against tide were made on each trial:

Pressure of steam.	Mean No. of revolutions.	Corrected mean speed in knots.	Slip per cent. + Positive. − Negative.	Remarks, &c.
45 lbs.	172·5	4·736	7·24 +	Griffith's screw 3 blades 3 feet pitch, 23½ in. diameter.
"	162·83	4·544	5·72 +	Do. with *deflector vanes*, 8 in number, 23½ in. diameter, and set to angle of 30°, fixed to after *stern-post*.
"	235·5	4·856	4.47 −	Pitch of screw reduced to 2 feet without vanes.
"	227·33	4·486	2·25 −	Do. with vanes as before.
"	120·	3·777	20·24 +	Pitch of screw '4 feet, with vanes as before.
"	180·83	4·555	14·90 +	Pitch of screw 3 feet, diameter reduced to 21 in., diameter of vanes 21 in., angle 30°.
"	226·16	3·854	13·64 +	6 bladed-screw model of *Charkieh* screw, diameter 23½, and 2 ft. pitch.
"	167.16	3·911	20·95 +	Griffith's screw 23½ diameter, and 3 ft. pitch, vanes set at 10° at boss, and 20° circumference.
"	162·66	4·250	11·73 +	The same screw vanes set at 0° at boss, and 10° at circumference.

The following comparison, with and without Rigg's deflectors, tried on a steam-tug on the Grand Junction Canal, is furnished by Mr. Arthur Rigg:

	Steam.	No. of revolutions.	Tension by spring dynamometer.
Without deflectors	70 lb.	240	$6\frac{1}{4}$ to $6\frac{1}{2}$ cwts.
With 2 deflectors	65 „	230	$7\frac{3}{4}$ to 8 „

FRICTION OF THE BLADES OF SCREWS IN WATER.

The Friction of the blades in their revolution through the water absorbs a considerable amount of the power of the engines, without adding any increase to their propulsive power. This resistance is commonly known to vary in proportion to the surface in contact, to the density of the fluid, and approximately to the square of the velocity. Many experiments have been made to test the *friction* of water passing through iron pipes, and the *co-efficient* deduced from them may be taken on an average at 0·0064.

The co-efficient of friction, deduced from the experiments of Messrs. William Fairbairn and James Thomson on revolving discs, is 0·002. It is probable that this last is too small for a screw blade where the surface has usually all the roughness due to a casting from either sand or loam; and, in order to determine more exactly the friction of water on the blades, some further experiments on large cast-iron or brass blades revolving in water require to be made.

Some considerable resistance is also due to the thickness which is given to the blades at their edges, as well as to the swell at their back, in order to have sectional area sufficient for the strength required. This resistance, as well as the friction on the sides of the blades, is so much abstracted from the power of the machinery available to propel the vessel.

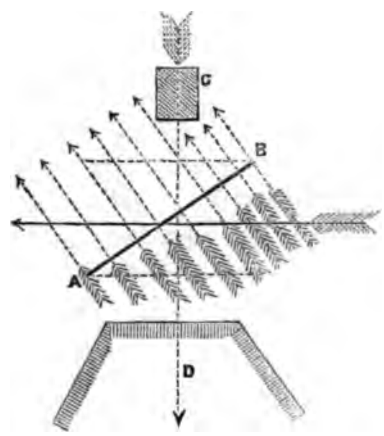
Professor Macquorn Rankine has written some admirable papers *On the Mechanical Principles of the Action of Propellers,* published in the "Transactions of the Institution of Naval Architects," in which he has mathematically investigated the subject, and given the algebraical expression for the resistance due to the friction of water on the screw, and thereby the consequent loss of thrust.

VIBRATION.—The vibration arising from the action of a revolving screw is due to several causes, but chiefly to the inequality of resistance during its successive positions round its centre, and to its being in too close proximity to the stern-posts, or sides of the ship.

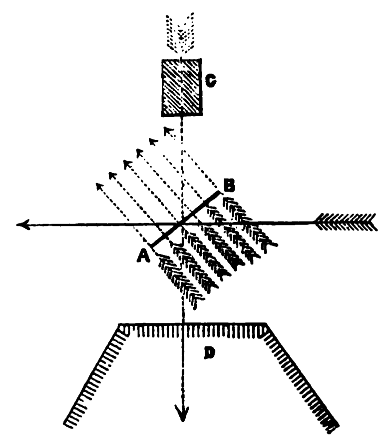
With respect to the latter, the vibration is probably due to the water which is carried round by the blades and is partially arrested in passing through the space between the lower and upper parts of the stern-posts. The larger the blades the greater is the quantity of water taken round by them. To this may be attributed the less vibration experienced with the French small six-bladed screw than with the larger two-bladed Admiralty screw. A broad stern-post, where there is a large body of *dead-water* behind it, will much add to the vibration, in consequence of the abstraction of the water from the stern-post as the blades pass by it, and the rush of other water to take its place. It is obvious that the nearer the

screw is to the posts the greater will be the impulse against them; and when it is considered that the periphery of a screw-propeller sometimes travels at the rate of 4000 ft. in a minute, the shock produced each time one of the blades passes, is very severe, especially when the outer extremities of them are broad and near the posts.

The following diagram will explain this action more clearly:



A *broad-bladed propeller*, showing action of currents on stern-posts.



A *narrow-bladed propeller*, showing action of currents on stern-posts.

A B. The edge of the blades.

C. After stern-post.

D. Foremost stern-post.

From the above considerations it may be seen that a screw with blades tapering from the centre to the periphery will give rise to less vibration than when the surface or breadth of blade is increased proportionally to the diameter.

There are two other reasons also, in favour of tapering blades; *first*, that as their breadths can be reduced nearly in proportion to the velocity of their different portions, *there will be* more uniformity of pressure throughout their surface.

Secondly, that as the resistance is in proportion to the depth immersed, the inequality of pressure between the upper and lower blades due to this will be less apparent the smaller the surface is at the larger diameters, for the nearer the centre the less the difference in resistance above and below.

The following particulars are extracted from the trials of different ships to illustrate the effect of small angle at the extremity of blade, that is, a small ratio of pitch to diameter of propeller, and the effect of velocity.

In the *Cruizer*, the slip is only two per cent., as below:

Diameter	Pitch of screw-propeller.	Angle	Revolutions.	Velocity in feet of circumference.	Slip.
ft. 9	ft. 6.8	° ′ 13 15	102·67	ft. 2900	Per cent. 2·02

The *Diadem* was tried with two screw-propellers of different pitch and the same

diameter, the displacement only differed eleven tons, and the indicated horse-power seventy-six horses.

The coarser pitch-screw was the *Admiralty two-bladed* with leading corners cut off.

The finer pitch-screw a Griffiths.

In order to make a better comparison, the speed given is that calculated after the two trials have been reduced to a common displacement and indicated horse-power:

Angle at extreme diameter of blade.	Velocity in feet at periphery.	Slip per cent.	Comparative speed in knots.
° ″			
30· 5	3041	33·76	11·7
27· 58	3086	26·51	11·97

In the *Amazon* a less power and a greater number of revolutions obtained from a screw of finer pitch, gave the greatest speed and least slip, as the following Table shows, the power in both cases being reduced to a mean and speed calculated therefrom for sake of comparison:

Angle at extreme diameter of blade.	Velocity of circumference in feet per minute.	Slip per cent.	Speed in knots.
° ″			
17 40	4173	7·27	11·97
16 16	4451	3·16	12·52

The trial of the *Bristol* is an example where an increased velocity of screw propeller diminishes slip, the propeller being the same. Thus:

Angle at extreme deal of blade.	State of weather.	Velocity of circumference in feet.	Slip per cent.	Speed of ships in knots.	Remarks.
22° 39″	Swell	3356	23·67	8·054	Half power.
		4204	19·67	10·596	Full power.
	Smooth	3696	19·61	9·344	Half power.
		4339	17·31	11·271	Full power.

The *Malaca, Liverpool, Aurora, Ajax*, and *many other ships* also showed on trial, that an increased speed of propeller gave less slip—that is, the slip with full power of engines is less than when using only half power.

At the same time it must not be overlooked that a great many ships show quite an opposite result, viz., that the slip is greater at full power than with half power. It may be supposed that in such vessels the resistance of the ship at the higher speed increases in a higher ratio than the resistance of the screw at its higher velocity, or that the surface and dimensions of the screw are better adapted to the lower speed.

It is in the larger class of vessels where this is most apparent, such as the *Warrior*,

Black Prince, *Bellerophon*, &c. Taking this last as an example, the following is the result:

Angle of extreme deal of blades.	Velocity of circumference in feet.	Slip per cent.	Speed in knots.	Remarks.
19° 36″	4350	1·40	12·103	Half power.
	5177	2·62	14·227	Full power.

An examination and comparison of the results of the trials of different screws on ships is often no easy matter, owing to the variety of circumstances which affect each trial, and from the great difficulty of obtaining accurately recorded results. The most reliable information may be gained from the trial of Her Majesty's ships under the direction of the Admiralty, where great pains are taken, more especially of late years, to get the true results under as nearly as possible the same circumstances. Several runs are made (generally six, with full power) over a measured nautical mile, or knot, at full steam, and the steam is not allowed to be shut off or throttled from the engines the whole duration of the trial, usually from two to three hours; but should anything casually happen which would cause a stoppage or slackness of speed, the whole trials have to be recommenced and fresh observations taken, which include not only the exact time in running each mile, but the indicated horse-power of each cylinder, and the total number of revolutions made while running the mile, the state of the weather, &c. After each trial the screw-propellers are measured both as to diameter and pitch, the draught of water fore and aft, the displacement and midship section of the ship duly recorded. But after all this, there are still circumstances which may affect an accurate comparison. The indicated power may not represent the actual power, from some fault or error in the instrument by which it is expressed. The power may not be so advantageously employed in one vessel or at one time as another, from undue friction or other causes, the form of vessel, and the state of cleanliness of its bottom; a few days laying in muddy water may materially alter the speed. The propeller blades may not have that rigidity so as to preserve the same pitch or angle during trial as when in a state of rest. There are also circumstances where the screws have to be adapted for the most economical way of working the engines; for example, a fine-pitch screw of itself may be better than a coarse one, but it may be more advantageous to have a coarser one, giving more slip with a decreased number of revolutions; but this is a question that has to do with the machinery, and depends on the relative size of boilers, pipes, passages, cylinders, the balance of the engines, &c., &c.

In conclusion, the foregoing remarks and the few examples cited, which appear to bear more prominently on the subject, can only be considered as an attempt to arrive at some general principles so as to determine the most suitable form of screw-propeller, and may be summed up as follows:

1st. That a screw-propeller should be in such a position as to be little influenced by the currents resulting from the ship's motion.

2nd. That an increase in the depth of water increases the resistance for the same surface.

3rd. That the smaller the angle of the blade with its plane of rotation, the greater is the effective thrust in propelling the ship forwards.

4th. That an increase in the velocity of propelling surface increases the effective resistance.

5th. That with an increase of velocity the surface should be reduced, in order to diminish the friction on the blades.

6th. That, in order to reduce vibration, there must be as nearly as possible an equality of resistance throughout every part of the blades, and throughout their revolution round the axis, and that the currents created by the screw should be as little as possible influenced by the retarding effect of the stern-posts, or sides of the ship.

CHAPTER III.

THE GEOMETRY OF SCREW-PROPELLERS.

By N. P. Burgh.

PRINCIPLES.—The common screw-propeller is simply a portion of the length of a continuous screw: for example, the thread portion of a carpentry screw cut into short lengths less than its diameter, will represent minute screw-propellers. In either case a band of metal of a certain width is wound round a cylinder on its edge, the cylinder corresponding to the boss of the propeller and the root of the carpenter's screw. In technical language the band is termed the "thread" of the screw, and the distance between these threads the "pitch",—the pitch being the main element in the consideration of the entire matter, as will be hereafter explained.

It is a fact more generally known than appreciated, that the elements of a screw are as a wedge in its action: for example, in Plate 1, Fig. 1, is an outline of a wedge of which A B C are the extreme points, and L the load at C; in Fig. 2, the load is at A, and is lifted in height H, a distance equal to A B, the travel of the wedge being equal to B C, or its length on the base line. On examining Fig. 3, the analogy between the wedge and the screw is obvious; H H is the half pitch of a screw, P P, the full pitch, and D the diameter. Suppose the screw to revolve one turn or circumference; A will be at B, and B at B^1, and the wedges A B C and B B^1 C^1 formed in principle; *i.e.* if the edge of the thread of the screw had been unwound from the barrel on which it is formed. Evidently also the lengths of the inclined planes, A C, and B C^1, depend on the diameter D and pitch P. The difference in the hypothenuse, A C, and the base line, B C, is a matter of simple calculation: thus $AB^2 + BC^2 = AC^2$, then $\sqrt{\overline{AB}^2 + \overline{BC}^2} = AC$. Therefore the base line of the wedge is equal to the circumference of the screw, and the height equal to the pitch, thus making the hypothenuse or inclined plane equal to the length of the spiral; or, to be concise, the three elements of the screw form a right angle triangle. Continuing our investigation of this matter, we come to the difference in the action of the revolving screw when advancing and when fixed at each end. Fig. 4 is a common screwed bolt with a block, A, on

Plate I.

THE PRINCIPLES OF THE COMMON SCREW PROPELLER.

Fig. 3.

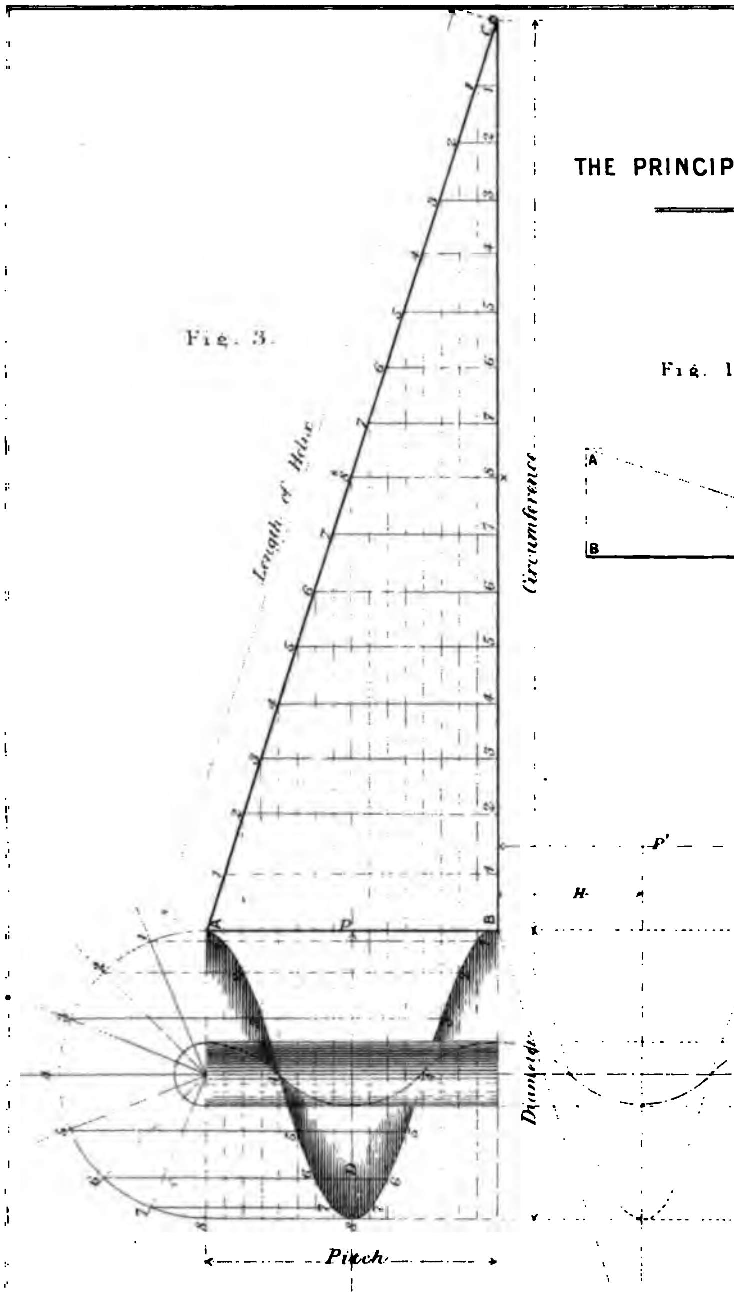


Fig. 1.

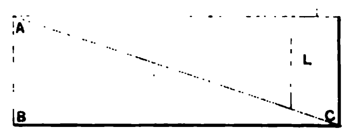


Fig. 2.

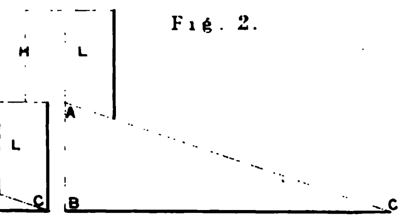


Fig. 4.

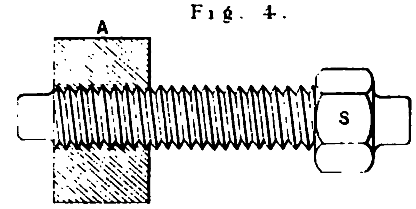


Fig. 5.

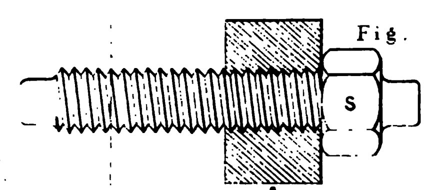
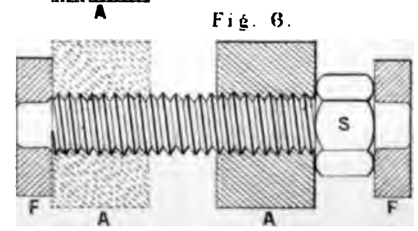


Fig. 6.



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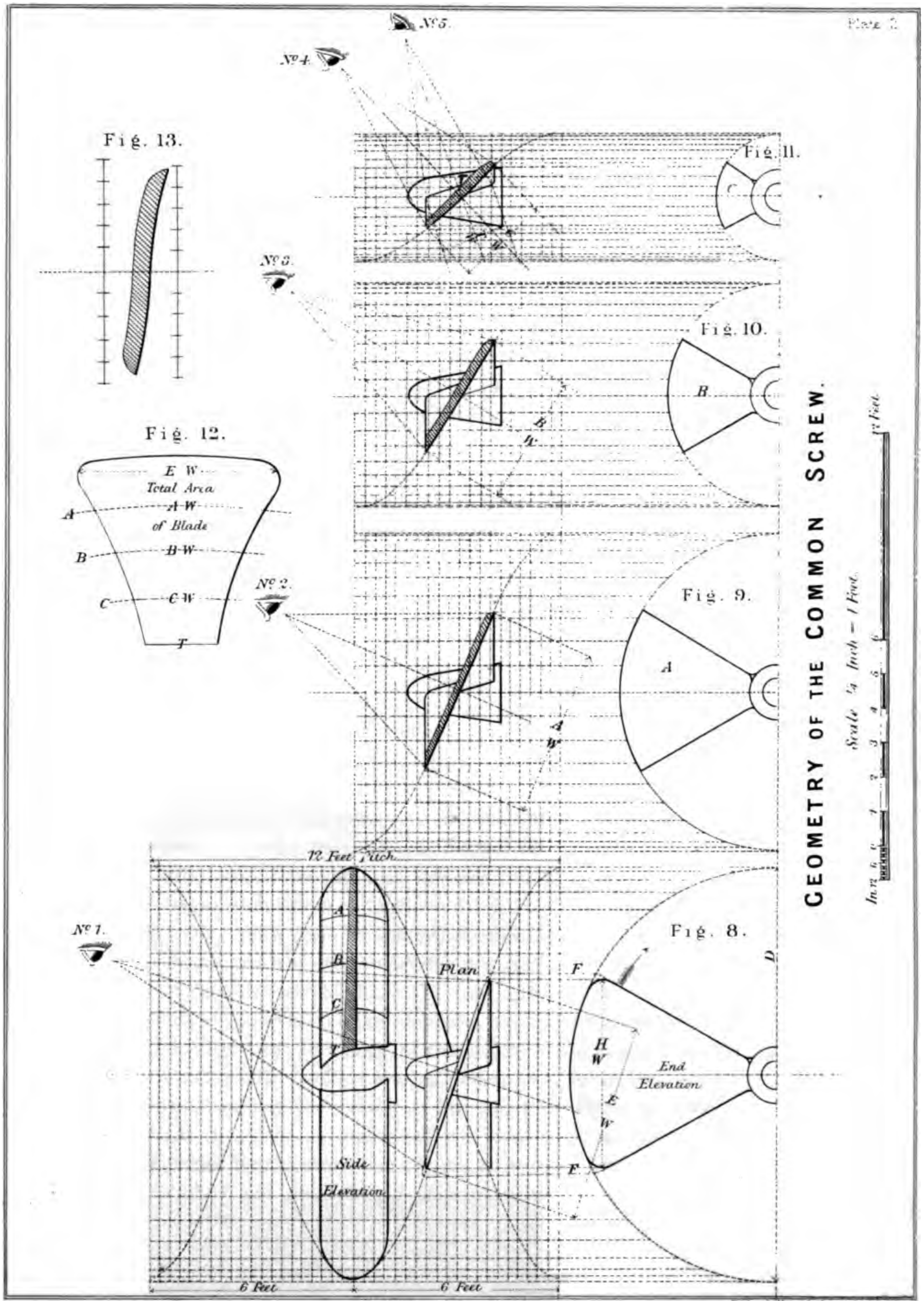

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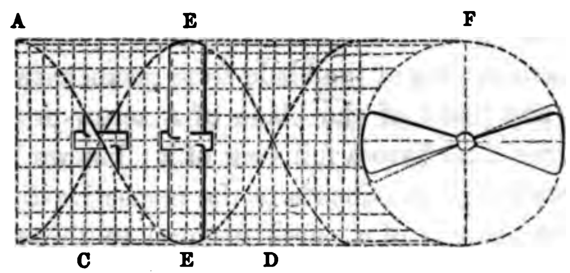
Hockey & Alexander lith. 43 Castle St Holborn

it. Let us assume the block, A, to be *fixed*, and the bolt turned by the head, S, until it has reached A, the position of the bolt would be as in Fig. 5. Referring next to Fig. 6, we find that the bolt is hung in bearings, F F, at each end and the block is *loose*. So that by allowing the block to slide on the screw when the bolt is turned, it A, reaches to F.

We have thus far described and illustrated the principle of the common screw, and we next proceed with its application for propulsion. The ordinary propeller is therefore simply a portion of one, two, or more spirals or threads wound round the boss or barrel, and the *length* of the screw defines the area of each blade to a great extent.

THE GEOMETRY OF THE COMMON SCREW-PROPELLER.—When the diameter, pitch, and length on the line of keel of a propeller are known, the mode of forming the curve of the edge of the blade is as shown by Fig. 7. Divide the semi-circumference of the circle F, which is equal in diameter to that of the screw, into an equal number of parts; also the half-length of the pitch, A E, into the same number of parts; then draw horizontal and vertical lines from the divisional points; divide the pitch into four equal main divisions at the three points, C, E, and D. Through the intersections of the vertical and horizontal lines draw curves in opposite directions, cutting each other at the centres over C and D. These will define what is generally termed "the angle of the blade," or, more correctly, the "helices." It will be noticed that the plan and elevations of the propeller are also shown in their respective positions, the definition of which will be more readily understood from Plate 2. Fig. 8 is the plan, side elevation, and end elevation of the screw, resulting from the intersections of the vertical and horizontal lines of construction. The mode of producing the dimensions of the propeller is simply as follows: Having settled the diameter, D, describe the radius; next draw the helices in the manner before explained; then determine the length, L, of the blade on the line of keel, which gives the angular or extreme width, E W, and the lines, F F, will determine the horizontal width, H W, in the end elevation. Should the leading and trailing corners of the blade be curved, E W and H W will be reduced proportionately, as indicated by the full lines in the plan and end elevation. Next, as to the side elevation; which is formed by the length, L, the diameter, D, and a portion of the helices of the top and bottom blades. The vertical section of the top blade is also shown, to which reference will be made; but first we must consider how to determine the form of the blade *below* the top edge, as shown in the plans. Commencing with a sectional plan, taken at A, in the side elevation; Fig. 9 is produced, the length on the line of keel being the same as in Fig. 8; next Fig. 10 is drawn, being a



DELINEATION OF THE COMMON SCREW.
Fig. 7.

section through B in the side elevation; and, thirdly, Fig. 11, being the section through C. In passing, it may be added that the length, L, is the same in all cases. Now, then, for the actual thickness in each case; this is produced from the position of the sectional lines, A, B, and C, in the side elevation, and transmitted to the corresponding sectional plans. The fact is apparent also, that, although the *pitch* of the blade is the same throughout its depth or distance from the boss to the extremity, the angles of the sections are all different—the shape of the blade starting at an acute angle with the boss, and gradually approaching the obtuse angle of the extremity or outer edge. It is equally certain, that if the side edges, E E, of the blade are radial lines from the centre of the boss, as shown in the end elevations, the *area* of the blade will be of the largest size; but if the radial lines, E E, were curved inwards, or towards the centre line, the area would be proportionately reduced.

Having settled the form of the blade according to the proportions agreed on, we must next learn the *actual* surface or area of the blade from geometrical sources.

Now, if we look at any point of the blade of a screw-propeller at right angles to that portion of the helix, we shall have a full view of it; but we have shown by Figs. 8, 9, 10, and 11, that the helices are proportionate to the respective diameters and pitch, or that each minute portion of the blade is of a curve unequal to those above or below it. To further exemplify this matter, let us presume the observer's eye, No. 1, to be at right angles with E W, in Fig. 8. He can see that, lineal width actually, but no more than that below the level of the line of vision, because the blade below that point alters in form and width; therefore the eye must shift accordingly. The observer, knowing this, he shifts his position to No. 2, in Fig. 9: here the lineal width, A W, is seen at a different angle to the former, or E W, and A W is less also. Next, then, as to the position No. 3, in Fig. 10: here B W is less than A W, and the angle is also different; proceeding next to No. 4, in Fig. 11, the angle and width, C W, are still more at variance with those preceding; and, lastly, No. 5 is the least or boss width, T W, of the blade, this position being at right angles to T, the connexion of the blade with the boss. This, then, is the method of viewing the *actual* lineal widths of the blade; if, however, the observer's eye is fixed, obviously the blade must shift accordingly and the line of vision is either lowered or raised, to correspond.

To return to the geometrical question, or the delineation of the actual area of the blade, and as an illustration Fig. 12 is introduced. Here the twist of the blade, or helical form, is not altered, but the lineal widths are set out on the various points from which they are taken. First is projected the lineal width, E W, from Fig. 8, and the true form of the edge of the blade when looking at it from the angle No. 1: the top curve here is a portion of an ellipse, or not an arc of a circle, as in Fig. 8, in the end elevation. It must also be noticed that the vertical heights, A, B, and C, of the sectional lines in the side eleva-

tion in Fig. 8 are indicated by the same letters in Fig. 12 : from these positions are demonstrated the several widths from the respective plans : for example, E W, in Fig. 8, is the same as in Fig. 12 : similarly A W, in Fig. 9, is the same as in Fig. 12 : corresponding also are B W, C W, and T, in Figs. 10, 11, and 12. Observe, next, that by drawing the sides of the blade through each point of intersection, on the section lines A, B, and C, in Fig. 12, the lineal area of the blade is correctly depicted as it is viewed by the observer from the several positions alluded to.

Now, it is evident that the way we have demonstrated this fact must be correct as far as the *lineal* length or width of the helical portion of the blade is affected. Another matter, however, is certain, viz., that the blade of the propeller presents a *curved* surface, and not a plane, to the water; obviously, therefore, the curved or helical surface must be *more* than the lineal angular surface. It must also be remembered that the actual surface is here to be obtained geometrically from lines and curves, and *not* essentially from the *actual* blade *after* construction. The points of vision, Nos. 1, 2, 3, and 4, in Figs. 8, 9, 10, and 11, are opposite the aft side of the blade, or the *trailing* surface which is raised, while the *leading* surface is uniform with the helix, as shown in the several plans. But this fact does not alter the optical demonstration, for the eye only perceives the outline, while the raised surface is unappreciated; consequently, the area of the outline remains the same; or, further, any surface projecting from the plane of vision, and not protruding beyond the limit of the plane's outline, will not affect the area measured by the eye's view of the superficial contents.

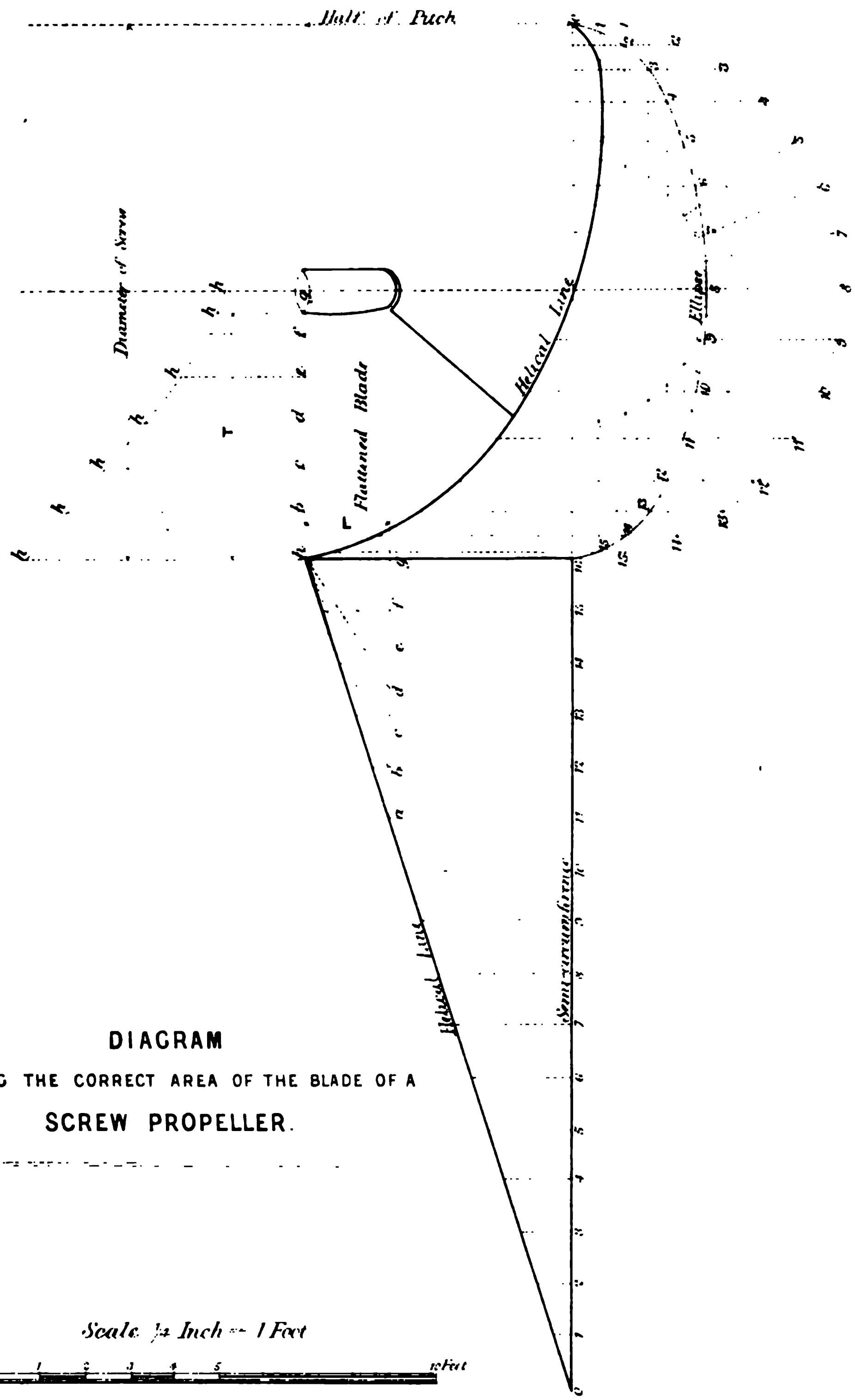
Next, then, comes the question of the real *helical* area of the blade, and the correct mode of obtaining an answer; geometrically, this is given by Fig. 13 : an enlarged section of one portion of the blade is only shown; the helical, or forward surface, and that behind it are divided into equi-distant parts, the total sum of each being represented respectively by the straight lines. The result is therefore conclusive that, by similar processes at the various sections of the blade, the actual helical area becomes a matter of the simplest calculation, because the actual lengths of the curved lines are thus readily known. The helix is thus spread out, or, in plainer terms, the curve is lengthened into a straight line, and the area of the blade becomes a *flat* surface of easy measurement.

In order to be certain that we have not overlooked any of the true principles of the subject we have been considering, it will be as well to recapitulate the facts that we have already demonstrated before going any further. In page 28, the description of Plate 1 is given, and in allusion to Fig. 3, the length of the hypothenuse is said to be the spiral or helical line unwound, while the base of the triangle is the circumference and the height the pitch of the screw. These facts being unalterable, it is obvious that they *must* bear a relation to the total area of the spiral, or agree relatively to any portion of it that may be retained, as in the case of that portion forming the blade of the propeller. Notice also in

Fig. 3, that the length of the helix is an angle dependent on the pitch of the screw or height of the triangle, that the circumference is the base line, and of course bears a relation to the *complete* diameter. Looking next at the screw, Fig. 8, in Plate 2, two blades are shown, and the *width* of each is determined by the *length* on the line of keel. Now, if the diagram, Fig. 3, in Plate 1, is accurate in principle, it must be also in practice, and will apply, therefore, in relation to the mode of producing the *actual* area of the blade, the truth of which must next be proved by another means subject to the same law that governs the formation of Fig. 3.

The Plate 3 is introduced for this purpose, the diagram being double the scale of that in Plate 2. In the present instance only *one* blade is represented, and that is presumed to be flattened to measure its area readily. Having, then, a given length of blade to deal with, a known pitch and diameter for the screw, the process of constructing the diagram in question is as follows: Draw a line equal to the length of the semi-circumference of the screw's diameter; from either extremity raise half the pitch vertically, connect these two lines by the hypothenuse; divide the base line into any number of equal parts; from the intersections raise perpendiculars; from *h* set down the length of the blade on the line of keel which is *h, g;* draw the horizontal line from *g* to *a*, which defines the length from *a* to *h*, on the helical line. Here, then, is this principle demonstrated; that if the base of the right angled triangle is *half* the circumference, the height *half* the pitch, and the helical line *half* the length of the spiral forming the edge of the blade, any smaller right angle triangle produced from the same sources as the larger figure must bear proportionately the same relation. Now, then, for the comparison: If the *full* diameter and pitch of the screw were represented by the main right angle triangle the dimensions would be doubled, but as *one* blade only is being dealt with, and its limits are within the *half* of the circle, *half*, therefore, of the pitch circumference, and helical line is only required to demonstrate the area in question. Obviously, also, the height, *g h*, must relatively produce the means of knowing the area of the blade in connexion. Now we must remember, again, that the helical line is virtually the top of the blade, or spiral spread out lineally, not curved in its natural state; therefore, if the helical line, *h o*, is the semi-spiral length in proportion to 16 *h*, then will *a, h*, be likewise the spiral or helical length unwound of the portion of the blade, whose length on the line of keel, is from *g* to *h*, or equal to L.

There may, perhaps, still seem to be a mystery about this; but if it is borne in mind that the *height*, L, of the smaller right angled triangle, *a, h, g*, is the length of the portion of the blade in action, and that the height is in a line with the *pitch*, or parallel with it, then the fact that the *actual* area of the blade is thus obtained will be readily understood. —If *a, h* is the length of the helix of the edge of the blade at its extremity, then the divisions at *b, c, d, e*, and *f* must bear similar relation to *sections* taken at those points. From *h* produce a line equal to the diameter of the screw, which bisect, and from *h* to the



DIAGRAM

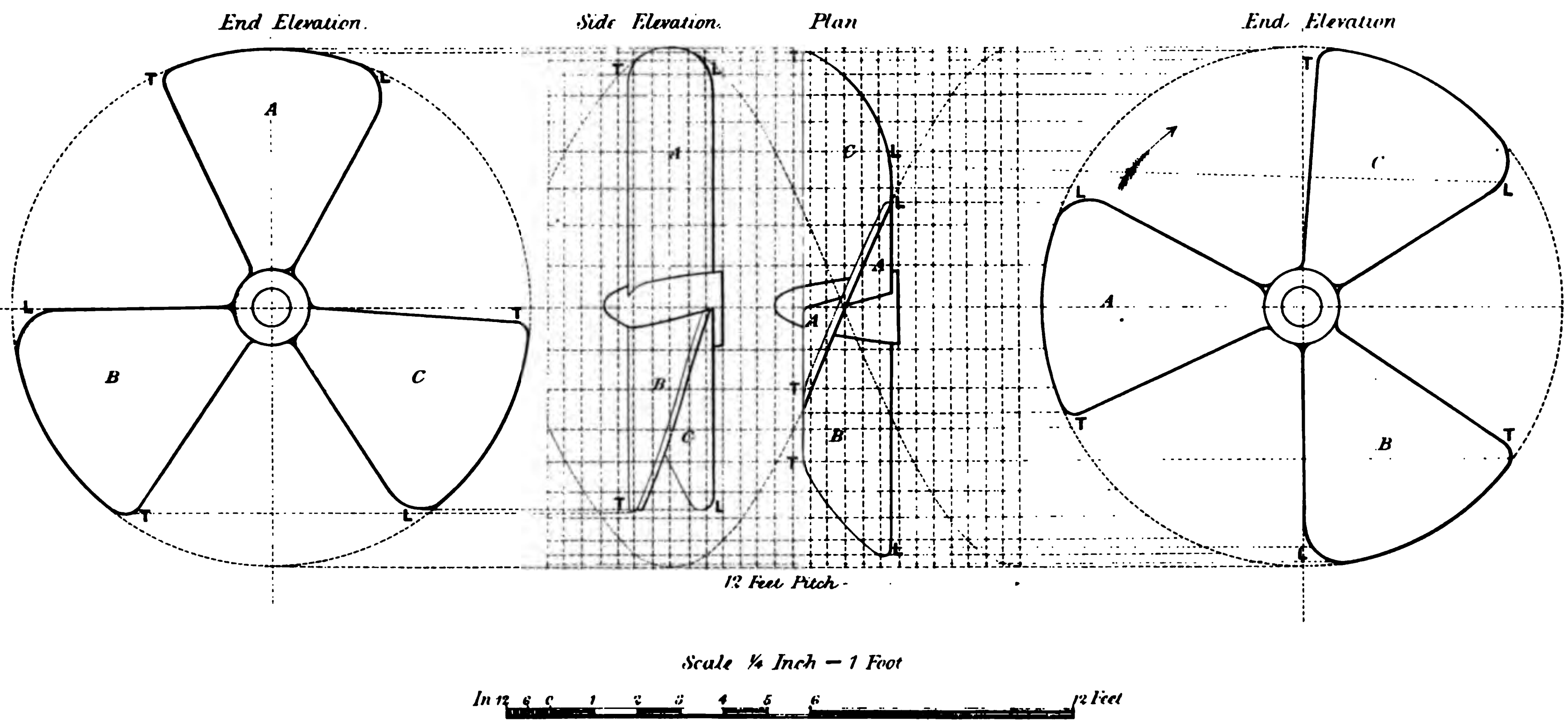
DEFINING THE CORRECT AREA OF THE BLADE OF A

SCREW PROPELLER.

Scale ¼ Inch = 1 Feet

Plate 4

GEOMETRY OF A THREE-BLADED SCREW.



Newbery & Alexander, lith 43 Castle St Holborn.

F. & F. N. Spon. 48, Charing Cross London

bisection, divide that portion into the same number of parts as in the line *a* to *g;* raise vertical lines from the divisional points; then with *a* to *h*, as a length, produce *h* to *h* vertically, and from *b h* also produce *b* to *h* vertically: proceeding, then, in the same manner to produce the remaining vertical lengths equal to the distances, *c h*—*d h*—*e h*—*f h* and *g h;* through the intersections last produced, describe a line which will be the side edge of the blade; then the outline connected by T will be the area of that blade. It is almost needless to add that the sum of the area is known by dividing the total length of the ordinates by their number of positions, and multiplying the product by the horizontal length of the surface within T.

It will be obvious that to produce the position and form of the blade, as shown, the horizontal line must appear longer than the angular limit; also that the curved extremity must be a portion of a helix; and to determine these matters, the principle already demonstrated must be again brought into action. To form the "helical line," represented as curved, draw a half circle whose radius is that for the diameter of the screw; divide this dotted semicircle into the same number of parts as the base of the larger triangle, or the semi-circumference; from the points of intersection produce the vertical lines as numbered O to 16. Describe next the lesser semicircle from the centre of the larger, the radius of the smaller being half of that of the greater. From the points of intersection on the main semicircle produce *radial* lines, cutting the inner semicircle; then from the latter points of intersection draw horizontal lines, cutting the vertical lines previously projected; and through these last points of intersection produce the ellipse, as shown: then with the lengths of the vertical lines, which have been already drawn from the base of the larger right angle triangle or the semi-circumference, as radii, and the intersections on the ellipse as centres, which are all respectively numbered, describe arcs, cutting the dotted vertical lines, and through those intersections produce the helical line, as represented; and the lineal length or width of the edge of the blade, as shown, will be as the line *a h*, or *h h*.

The means of obtaining the area of the blade being thus fully explained, we must next direct attention to the geometrical method of showing the position of any number of blades. It will be remembered as an example to commence with, that in Fig. 8, Plate 2, the plan and side elevations of *two* blades are shown, but the end elevation of one only, the latter view being sufficient, simply because each blade being a duplicate, the repetition was not requisite for demonstration, therefore we next allude to—

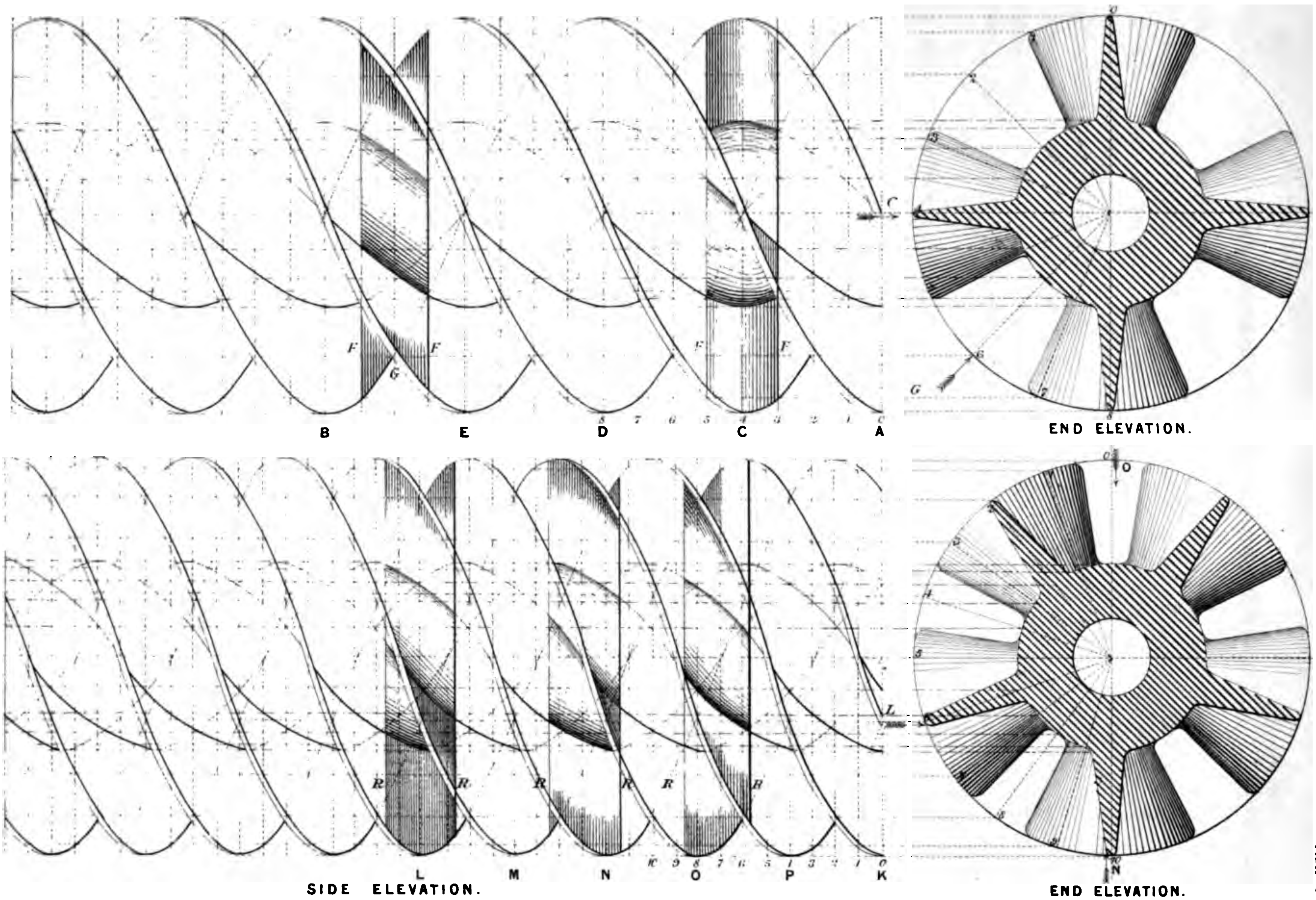
The Geometry of the Three-bladed Screw.—The illustrations in Plate 4 are the geometrical delineations of a three-bladed screw, showing the positions of each blade in plan and elevations, the mode of setting out the several positions in the respective views being as follows: Describe first the circle equal to the screw's diameter; divide *half* the circumference into any number of equal parts. Set out the pitch on tangents parallel with the centre line, divide *half* the pitch into the same number of parts as the semi-circumference,

and repeat the division to the opposite extremity of the pitch, if desirable. Produce next the horizontal and vertical lines from the respective intersections, and draw the helical lines, as shown. Having defined the length of the screw on the line of keel, and the amount of corner to be cut off at the leading and trailing points, L and T, draw the end elevations of each blade, as shown; then the elevation on the left will produce the side elevation, and that on the right the plan. To render this matter to be fully understood, each blade in each view is similarly lettered A, B, and C, so that the several positions of the blades correspond with each other accurately, thus not requiring further explanation.

THE GEOMETRY OF THE FOUR AND FIVE-BLADED SCREWS.—The geometry of the examples of screws now under notice, is, of course, the same in principle as that preceding; but as it often occurs that when a student has to draw a propeller with more than two or three blades, he is puzzled for a time, although he may remember the fact that the delineations of all the blades are alike. The point that is the most mysterious to him is, how to obtain the position of each blade in the plan and side elevation corresponding with the end view. To render this question of easy understanding, the illustrations in Plate 5 are introduced. The four-bladed screw-propeller is merely a short length, or portion of a long screw of a four-thread pitch, it will be seen; but for the purpose of making all clear in this matter, we will explain how the particular positions of the blades are produced. The circle, whose diameter corresponds with that of the screw, is first drawn, next horizontal and vertical centre lines; half the circumference is then divided into eight divisions equidistant; the pitch of the screw is next set off on the two parallel tangents projected from the circle; this length is bisected, which produces the two half-pitches, each of which is also divided into eight equal parts; horizontal and vertical lines are then drawn from the divisional points on the circle and tangents. The helical line, A B, is then drawn through the intersections, which lineal length, A B, is the pitch of one thread. Now, as there are four blades there must be four threads, three of them, C D E, being within the pitch, A B, but all of equal pitch and form. The process of producing the three helices is merely a repetition of that for the first helix, excepting the lines of construction, which are available without alteration or addition. Continuing the helices to the extremity of the screw, the four pitches are extended, and as these constitute the *edges* of the threads only; next the boss connexions must be shown. Starting again at the circle, radial lines are drawn from the divisional points which divide the half circumference of the boss circle into the same number of parts as the outer circle. Two parallel tangents are then projected from the boss circle which form the boss longitudinally throughout the length of the screw; lines of construction are then drawn which intersect with the vertical lines already alluded to. The boss helices are then formed exactly in principle as those preceding.

So much for the screw of a length exceeding the pitch; but we require only a very slight portion of this length for propulsion, and our main purpose is to delineate that

GEOMETRY OF A FOUR AND FIVE BLADED SCREW.



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The student can now, from the preceding remarks, arrive at a definite conclusion as to the geometry of the screw-propeller, which, as we said before, is merely a matter of the simplest order—first starting properly, and the remainder is almost a mechanical operation as far as thought is affected. We have plainly shown in Plates 2 and 4 what the ordinary method is for drawing screws of that class for actual construction, and the present illustrations in Plate 5, are founded on the same principles as before alluded to; but our present aim is again to render the entire matter more clearly, if possible, than before, to the student, who may require that additional instruction. As a conclusion, therefore, if it is borne in the mind of the student that each blade of a propeller is merely a portion of the thread of a screw, and that any number of blades introduced are merely a corresponding number of threads from pitch to pitch inclusive, he will understand the entire subject concisely. He will appreciate also the fact that six, eight, or any number of blades of a screw-propeller can be as correctly and as easily drawn as two or three blades; for, once settling the proportions and positions, the rest is, metaphorically, a matter of plain sailing with a fair wind.

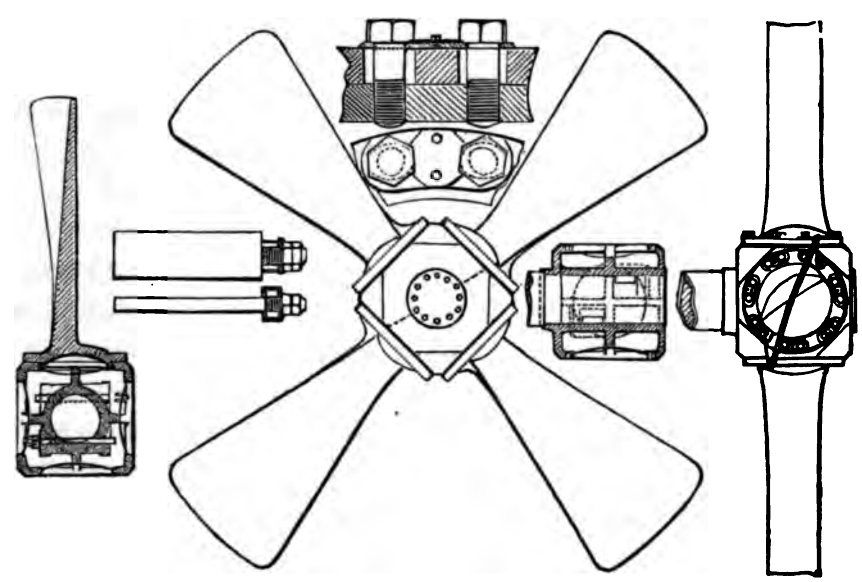
THE GEOMETRY OF THE BLADE OF AN UNEVEN PITCH.—This branch of the present subject partakes of the "principles" acknowledged by the inventor, whose screw-propeller bears his name, the "Mangin" screw. It is not now the purpose to treat of the cause and effect of this principle, but rather to give the practical geometry as illustrated by Plate 6. Although the "principles" of the blade's action in the water are now ignored, the geometrical "principles" necessary to produce the form of the blade must be considered. It must next be remembered that the mode of producing the helical line is by the division of the pitch and the circumference of the screw into an equal number of parts, all the divisions having a strict relation to each other. Now, if this rule is absolute, and in no form can be altered, certainly if half of the pitch only is required, half of the circumference will be sufficient to correspond geometrically. Again, then, if half the pitch and circumference will produce the half of the helix of the blade, or its complete angle—which it does, as already demonstrated—and if only one-fourth of each helix is required in this case for the half portion of the blade, then *one-fourth* only of each pitch and circumference is sufficient also for the geometrical demonstration. We again learn from these facts that the *complete* helix bears a relation to the *complete* pitch, and likewise to the *complete* circumference, which is the geometrical principle now under notice. Referring again to Plate 6, the two helices are thus produced: Divide one-fourth of the circumference into any number of parts, and one-fourth of the pitch into the same number to correspond, project the horizontal and vertical lines as before explained, and the helical line can be readily drawn as illustrated. Set off D E and D F equally, if so decided on, which will produce G and H unequal; but if G and H must be equal, then D E and D F will be unequal. These reversible distances or proportions are the result of the corresponding positions of the points of contact of the helices of the unequal pitches; for example, if the

connexion of the helical lines is at the centre of the length of the blade on the line of keel, then will G and H be equidistant from the centre of the connexion. But if the centre of connexion is on the *angular* length or width of the blade, then will D E and D F be equal, and G and H proportioned as before explained. The end elevation will depend on the plan in this case as in others, and is, therefore, produced similarly as shown.

THE GEOMETRY OF A VARYING PITCH.—The first matter here to be noticed is the amount of pitch required to produce the construction of the central helical line, and from that the constructing angle of the blade. Now, in the Illustration Plate 6, there are *two* helical lines of 16 and 20 ft. pitch respectively, the mean of which is 18 ft., which is the constructing pitch of the blade. It will be seen that the blade in this case is secured by a flange to the boss; while the requisite amount of oval in each of the bolt-holes in the flange is entirely due to the variation in the extreme pitches.

The blade is first set out from the 18 ft. pitch in the usual manner already explained and illustrated, and from the two extreme pitches next is produced the relative helical lines as shown, and the points where these helices intersect with the flange circle, will be the marking points to indicate the relative angles of the blade, also the length of the oval of each bolt hole.

The geometrical diagram under notice refers to one blade, but it will be well again to mention that the principle is equally applicable, whether two, three, four, or any number of blades are required; therefore the mode of producing the several positions for each will be alike. If the drawing is required for three blades, refer to Plate 4; if for two, refer to Fig. 8, in Plate 2; and if for four, refer to Plate 5, and also to Fig. 14, which is a



PLAN AND ELEVATIONS OF A MODERN 4-BLADED SCREW-PROPELLER.
Fig. 14.

propeller with four blades, each being at an angle of 45° in the end elevation. The plan on the right hand is presumed to be the direct view of three blades, the fourth being below the boss. The extremities of the blades in plan beyond the boss are broken off to economise space, but their final outline will be readily understood from the side elevation in Fig. 8, Plate 2. This will be more fully appreciated, doubtless, if the plan in Fig. 8 were supposed to be laid on the side elevation, which conjunction would be the complete plan, combined with a side elevation of a *four*-bladed screw. Or if further requisite, as an explanation, it may be again stated, that direct views of a four-bladed screw in plan and side elevation, are *always alike* respectively.

The sections shown in the illustration, Fig. 14, also refer to the mechanical question of shifting the angle of the blade and the mode of securing it, to which attention will be duly given, together with a repetition of the illustration.

CHAPTER IV.

THE HISTORY OF THE GRIFFITHS' SCREW-PROPELLER, BY THE INVENTOR,

ROBERT GRIFFITHS, ESQ.

IN accordance with what Mr. Burgh states on the first page of this work to be his object, I have purposely written a few observations which I have noted during the several years of my practical application to the development of screw-propulsion.

My first lesson in this matter was when witnessing some experiments made by Captain Erricson on the Regent's Canal about thirty years ago, and from what then occurred, it seemed to me certain that the subject of screw-propulsion was not understood. About ten years afterwards, having some spare time, I occupied it in making experiments with a small model screw-boat, the propelling power being a strong spring, and the small screws used being made of sheet zinc. My first idea was to ascertain what portion of the screw's disc was most effective in propelling, or, still better, what was the relative efficiency of the length of the surface of the blade for the purpose of propulsion, or the relation of the outside of the disc to the central part. In order to ascertain this, I decided to fill up the central portion of the screw with a sphere, so that when I had ascertained the loss of efficiency caused by this alteration, and allowed for the power required to drag the sphere through the water I could determine the *loss*—as I then imagined would occur—which resulted from taking away from the screw the portion of the disc occupied by the sphere. In order to carry out this idea, I had a wooden sphere made one-third of the diameter of the screw; and to this I fixed the outer portions of the zinc blades of the diameter and pitch according to the "common" or "Admiralty" screw, which then I believed to be of the best proportions. When the screw thus altered had been tested, to my great surprise I found that instead of a *loss* taking place, there was a slight *gain* in the speed of the boat, compared with the power then and previously exerted. The size of the sphere occupying the central portion of the screw was then enlarged, and I found that by doing so the velocity of the screw was increased, but without effecting a proportionate increase in the speed of the boat.

I next tried the effect of reducing the size of the sphere, and found that the reduction of it from one-third to one-fourth of the diameter of the disc or screw produced scarcely any alteration in the effect of the same; but any reduction below one-fourth caused a loss of speed for the ship.

Having thus determined what proportion the size of the boss at the centre should bear to the diameter of the screw, I next directed my attention to experiments with a view to ascertain what portion of the blades was the most effective. My first experiment with this object was to reverse the shape of the blades by putting the narrow parts to the outside, and the wide parts inside, or from and towards the centre of the disc; indeed, just the contrary to what was the usual practice. I soon found that I attained a better result with the blades formed in this manner than with any other. I consequently tried blades of different proportions, which eventually led me to conclude that the best proportion for a screw-propeller was to fill up its centre with a sphere equal to *one-third* of the screw's diameter, and the width of the blades just over the sphere should also be equal to *one-third* of the screw's diameter, and at the points equal to *one-ninth* the diameter; and it has often surprised me, after many years of experiments on large and powerful ships, that I have not found it necessary to make any great deviation from the above proportions, which I concluded as the best for the small model I first used.

My attention was next directed to making the blades of the propeller adjustable, so that the pitch of the screw could be diminished or increased when under way, or even feathered when the ship was under canvas only; this I deemed especially advantageous, since the enlargement of the boss or sphere, causing no loss or obstruction, allowed sufficient room to make such arrangements as were requisite. And soon after my first patent was taken out, I fitted a movable-bladed screw on a small boat belonging to the Steam Navigation Company at Bristol. This ship had a single cylinder of about 20 in. diameter, having a 2-ft. stroke for the piston—geared 2 to 1, or nearly so. I had slots in the sockets where the shanks of the blades fitted, and through these slots the levers were fitted to the shanks of the blades, which latter were acted on by a sliding clutch on the screw shaft; this clutch was acted upon by a bell crank secured to the stern post, and connected to the deck of the ship by a slight rod. I was much surprised to find, that when the engine was going at full speed, I could either increase or diminish the pitch of the screw by the slightest exertion with my finger on the connecting-rod from the sliding clutch. When the blades of the screw were at a pitch equal to one and a quarter of its diameter, the water had *no* tendency to increase or diminish the pitch; but when the blade was put at a coarser pitch, the effect was to cause it to be still coarser, and when put at a finer pitch, the result was opposite, or finer in pitch.

Experience, however, soon proved, from numerous trials and careful observations, that the risk of derangement attending the requisite machinery to vary the pitch was too

great to admit of general success, and the supposed advantages to be derived therefrom were for practical purposes far less than generally expected; in fact, it soon became apparent to me that the only actual advantage gained by feathering the blades of a screw-propeller is, that the blades when in that position, offer no obstacle to the progress of the ship when she is under canvas only, or when steam power and the screw are at rest.

My attention was next directed to the construction of my screw-propellers in such a manner as would combine the greatest possible stability with increased facilities for altering the pitch or replacing a broken blade in case of an accident, without the necessity of docking the vessel.

When I first brought out my form of screw-propeller it appeared so contrary to the opinions of marine engineers generally that most of them ridiculed the idea, as they thought it contrary to practice and common sense: but very little consideration will convince the most sceptical that the form of my screw-blade is quite correct. Nature has given to *swift* birds and fishes tapered and pointed wings and fins, but to the *slow* birds and fishes, broad wings and fins. In proportion to the speed with which bodies move through fluid, will be the amount of the particles of that fluid put in motion, and as the *points* or outer edges of the propeller blades move through the water at double the speed of the *inner* part or at half of the diameter of the screw, also being nearer the boss, the blades consequently require to be only one quarter as wide at the points as at the widest part near the boss, to put a column of water in motion equal to the screw's diameter; for example, with a two-bladed screw of 17 or 18 ft. in diameter, revolving at 60 revolutions per minute, the points of each blade will follow each other every half second, and as each blade strikes the water and puts it in motion it will sustain it in that state or very nearly so until the next blade strikes it, hence the slight difference, in retarding the speed of the engines between a 2, 3, or 4-bladed screw. I may as well state that I have not deviated from the proportions for the sufficient strength of screw-propellers as given to the Admiralty engineers from the first, and I consider those proportions to be as nearly correct as it is possible to get; having made an immense number of them without having had a single failure, except from blades which have been in contact with wrecks or other submerged floating substances.

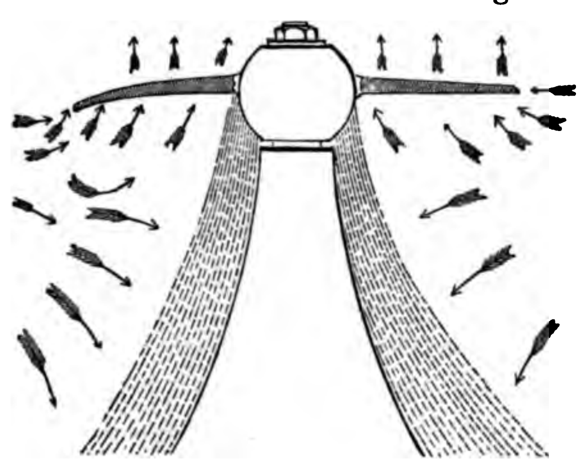
There has always been a diversity of opinion amongst engineers with regard to the angle or curve of the propelling surface of the screw-blade, and a general opinion prevails that it ought to form a true screw at whatever pitch the screw is fixed to work. I have taken great pains to prove this and get at the best form. I believe also that most engineers are aware that if two screws are made in every way alike, with this exception, that one has a flat or straight blade, and the other curved, or forming a true screw, there will not be the difference of half a knot obtained in the speed

of the vessels so fitted when the power and all other circumstances are alike. Now, taking the pitch of the screw at the centre of the blade, the flat blade will be at the point considerably coarser in pitch and at the root finer, while the true screw, as a matter of course, will be at the same pitch at all parts of the blade. From experiments I have come to this conclusion, that the best pitch for a screw-propeller in all cases, where circumstances will admit, is to be as nearly equal to $1\frac{1}{4}$ of its diameter as can be made, but it seldom occurs that this can be done, especially in small vessels of light draught, for which often the pitch of the screw is nearer equal to twice its diameter, or perhaps even more.

I have always constructed my screw-blade patterns at a pitch equal to $1\frac{1}{4}$ the diameter of the propeller and secure the blades in the boss at whatever pitch that will allow the engines to work at the speed intended by the maker; accordingly the pitch of my propellers is taken at the middle of the blades half way between the boss and point.

Every engineer, of course, is aware that when a screw-propeller blade is constructed as a portion of a true screw, say the pitch being $1\frac{1}{4}$ of the screw's diameter, and then fixed on the boss at a pitch equal to $1\frac{1}{2}$ or more of its diameter at the centre of the blade, the points of the blades will be of a coarser pitch, or more than equal to $1\frac{1}{4}$ diameter of the screw, and the pitch of the roots of the blades at the boss less; and also that the coarser the pitch of the screw is set at the centre of the blades the greater will be the difference.

I also find great advantage in constructing my screw-blades to incline forward, the curve commencing from the centre of the length of the blade, and extending to its point towards the ship; which result I account for in the following manner: when the ship is under way the screw is supplied with water from the after-current, and this current has to be turned from its natural course, which is to fill up the space or channel that the ship has left, and also to supply the screw with propelling resistance, so that when the points of the blades bend towards the ship they meet this current and offer certain resistance to the power employed to work the screw, or what may be termed a greater *bite* to propel the ship, as shown by the diagram, Fig. 15.



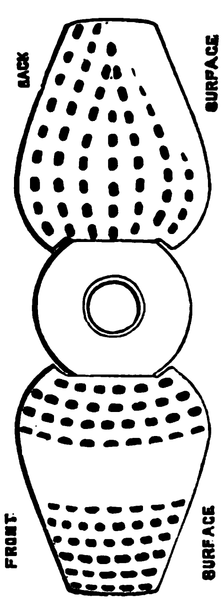
A plan of the currents meeting the straight and curved blades of the propeller.

Fig. 15.

I may add that I have always proved it advantageous also to bevel or curve the leading edge of my blades, for it is well known to every one who has examined an old screw-propeller after it has been much used, that the part which shows most wear is on

the forward side of the leading edge, so much so, that I have often seen old propellers, both of brass and iron, honey-combed, and in some cases worn until the metal was broken off by the water at these parts. This occurrence obviously has been done by the column of water striking that part of the blade as it divides it when passing; for when the screw is at work each blade strikes and drives the water back through its disc between the blades at a speed due to the angle or pitch of the screw, and the after-current follows it, which the next blade strikes, and as the screw is moving forward with the ship, the current that has been made to move backwards by the preceding blade strikes the leading edge of the blade on the forward side, which causes the great wear, as before noticed, on that part; and it is my opinion that if the resistance which is thus made to the blades were *lost power*, it would have been fatal to the screw as a propeller; but the power thus exerted from the water on the forward sides of the blades is given back by acting on the inclined surface, and thus forces itself around the screw, so that the only loss incurred is the friction due to the contact, and I find by bevelling the leading edge of the blades forward I reduce the wear that takes place.

Starting again almost from my outset,—when I first commenced applying my screw-propellers, I put one on a vessel that was in dock, and I then dropped spots of candle grease all over the blades of the propeller on both sides, and after some trial, on the return of the ship to dock to alter the pitch of the screw, I found the tallow taken off on the after propelling side of the front surface, just across the middle or widest part, and on the forward side on the leading edge of the back surface, as shown by the diagram, Fig. 16, and I considered it very surprising at the time that *any* portion of the tallow should be left on the blade; but since then I have seen propellers that have been at work for months with grass grown over them, in some places 3 or 4 in. long, so that there is very little doubt that a film of water naturally sustains itself on the surface of the blades when the screw is at work, and it is only removed from those parts when the greater pressure comes upon them.



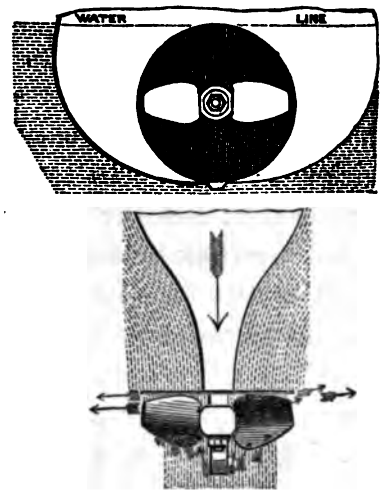
The Griffiths' screw-propeller with spots of grease on the blades to indicate the real action of the water.

Fig. 16.

In designing screw-ships the most important feature for ensuring the required speed is by having the after part, or run, made so as to allow time for the flow of water to fill up the space the ship has left, as well as to supply the screw with water; for, obviously, unless the screw can meet with a sufficient supply of water freely, a good result can never be obtained. It is of little consequence, however, what is behind the screw, or rather what becomes of that water after it has gone beyond the screw, as the screw has advanced from it, but undoubtedly any obstruction to the water getting freely to the forward side

of the screw will cause a serious loss in the speed of the vessel. The experiments made with the *Dwarf* by the Admiralty, in 1846, proved this most conclusively. When she was tried with a *fine* run her speed in knots was 9·1, with 32 revolutions of the engine; and when her lines were filled out with three layers of planking, so as to represent a ship with a *full* run, her speed in knots was reduced to 3·25, with 26·5 revolutions of engine.

Referring now to another experiment. Some time since, I fitted a small model with a disc of about equal diameter to the screw, placed in front of the screw; when the screw was put in motion the boat went astern, instead of ahead, for as the screw could not get its supply of water on the forward side, it drew it in from abaft, and discharged it at the periphery, as shown by the diagram, Fig. 17.



The effect of a disc in front of a propeller.
Fig. 17.

I believe, ship-builders generally pay too little attention to the quantity of water which is required for supplying the screw, as well as filling up the space the ship has just left, for when the midship section of the ship is passed, the water has to flow in and fill the void or channel left by the ship's progress; and should the after portion or run of the ship be too short in proportion to the speed due from the power employed, so that there is not sufficient time for the water to close in, and exert the natural pressure on the run, a partial vacuum is caused, increasing the resistance of the ship, and depriving the screw of the supply of water which is so essential to its efficiency. The water required to supply the screw for a ship of full-engine power will be nearly one-half the quantity required to fill the channel formed by the ship's progress, to that of lesser proportionate power.

A screw to be of good proportions for a ship of full engine power, its diameter ought to be nearly equal to one-half the beam, and as a general rule, when the progress of the ship is 12 knots, the screw drives a column of water through its disc at the rate of 14 or 15 knots, and this column of water is taken from what would otherwise have gone to fill up the channel formed by the ship's progress through the water. I consider this a most important feature in the efficiency of screw-propulsion, and one which has not received due attention from ship-builders, and consequently a great amount of power is frequently lost. Whilst on this subject I may as well mention an occurrence I witnessed some years since, when trying a ship in Stokes Bay. After one of the runs the ship was ordered to be turned, and when the helm had been put hard over, and she had got round, the helm was released, at the same moment the engines started off suddenly at a great velocity; they were at once stopped, for all we who were interested, on board, expected the screw had broken. After due examination, and finding all apparently right, the engines were again started, when the following peculiarity occurred—I happened to be looking over the stern

at the time, taking observations, and noticed that, instead of the usual current of water going away from the screw, there was a large body of water revolving with it; this was, doubtless, caused by the helm directing a large body of water on to the extremities of the screw, whilst, at the same time, the screw was unable to get its proper supply in the proper manner, thus causing a body of water to revolve with the screw.

I think, before concluding this paper, it would be as well to mention one subject, about which the most erroneous opinions have always prevailed; I mean what is commonly called "the slip of the screw." It has been frequently asserted that it is the same as the slip of a locomotive driving-wheel when the power is greater than the bite of the wheel on the rail; but the cases have no analogy. With the locomotive the power is partly expended in revolving the wheel on the rails, instead of propelling the carriages; but, in the case of the screw, it is virtually the action of a fan which drives through its disc a column of water equal to its diameter, and at a speed due to the pitch or angle of the blades with the screw-shaft; and, whether the ship is at her moorings or under way, the thrust on the screw-shaft equals the resistance of the column of water that is driven through the screw, as it were, and counterbalances the power exerted by the engines—minus friction—so that the resistance thus obtained by forcing the water backwards is also equal to the force or thrust that is transmitted to the screw shaft for propelling the ship. The water in which the screw works is an eddy that follows the ship at the same speed, or nearly so, varied by the proportion existing between the form and length of the run and the speed at which the ship is driven through the water; and therefore if a patent log were placed in the screw opening, when the ship is propelled by canvas only, it would not even approximately indicate the speed of the ship.

I have tried the following experiment in a paddle steamer. From the after-cabin window a small sphere, attached to a line was dropped down into a position corresponding to the screw opening in a screw-ship, the vessel was then going at a speed of 2 to 3 knots per hour. The sphere moved about in different directions, until it gradually travelled behind the rudder, and left the ship; but, when the speed was increased to 11 and 12 knots per hour, the sphere, when lowered into the same position as in the first experiment, gave a twirling motion in the eddy, and then went forward under the ship's quarter, and *remained there*. It appears to me, therefore, that the slip of the screw is the difference between the speed of the wake or eddy water and that with which it is driven backward when passing the screw; and there is consequently, reason to believe that this difference is from 60 to 75 per cent. instead of from 10 to 15 as generally supposed.

If a ship were fitted with two screws of equal diameter and pitch, the one in front of the bow of the vessel and the other in the dead wood, and both be left to revolve freely when the ship was propelled by canvas, the screw in front of the bow of the vessel would indicate nearly the speed of the ship, but the one in the dead wood would hardly indicate one half of the speed the ship was actually making.

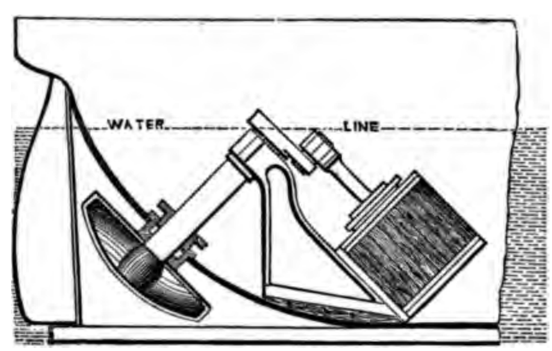
No sailor who understands his profession would think of determining the speed of his ship from the indications of either the common or Massey log before giving out as much stray line as would allow the log to get out of the after-current formed by the ship.

I do not consider that what is generally termed "slip of screw" is power lost, as it often happens that the propeller which shows the *least* slip gives the *worst* result; for it is perfectly feasible to make a screw to do its work almost without any slip by inclining the blades forward towards the ship. This was tried with H.M.S. *Flying Fish* in 1856, and it was then ascertained that, with an ordinary screw of 20-feet pitch, the engines made 76 revolutions per minute, but, with a screw of the same diameter, the same surface and form of blades which were inclined towards the ship, with a pitch of 16 feet, the engines made 76 revolutions as before; therefore making about 3 knots per hour less slip, whilst the speed of the ship remained the same throughout.

It appears to me that one of the most difficult, as well as the most important points to arrive at correctly, is, the pitch required to give the best result in relation to the power and form of vessel that the screw is applied to; for, unless this is properly ascertained, the probability is that the ship may be employed for years at the loss of half a knot or even a knot per hour in her speed. I am in consequence convinced that the majority of the merchant screw-ships of the present day run at least half a knot short of the speed they should realise if their screws were of the right pitch and diameter. If the cost of coals that would be required to obtain this last half knot in our merchant ships were duly ascertained it would be enormous; and the needless outlay could be saved were the merchant ship-owners open to conviction of this fact. No doubt there are some merchant ships which have the pitch of their screws made comparatively correct, but not from the result of scientific calculation and construction, but from accident alone—similarly as in the lottery of guess-work some may now and then draw a prize. I knew a case of two sister vessels built from the same lines, engines quite alike, and by the same maker, and fitted with screws of the same form and pitch; when it was found after a few months' trial, that one ship was nearly half a knot faster than the other. The engineer of the slow ship then put a foot more pitch to his screw, which actually converted the slower ship into the faster. I also knew another case where a steamer whose speed being unsatisfactory, a foot was reduced in the pitch of her screw, when an increased speed of one knot per hour was obtained without any addition to the speed of her engine. Further, I have known the pitch of a screw increased in about the same ratio on another ship, when the speed of the engine was reduced about 10 per cent. but the speed of the ship remained the same.

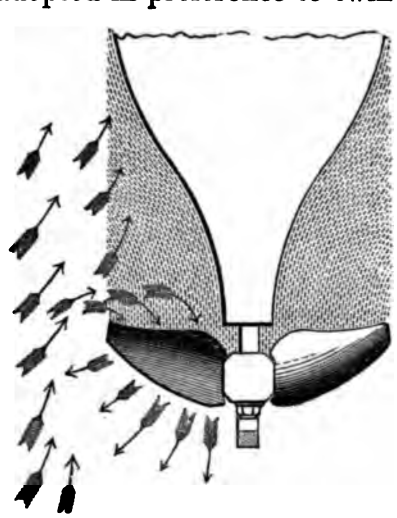
It is customary, when the result obtained from the screw is not satisfactory, that the engineer thinks he can improve upon it by making a new screw, into which he will probably introduce some *imaginary* improvements, mostly in the form of altering the pitch. The result proving favourable he attributes it immediately to such alterations and supposed improvements, and the delusion continues until he has tried it upon one or two other

vessels, when he will most likely find the result to be quite the contrary. There never can be any rule laid down for finding the best pitch required to any given vessel unless all matters are noticed, as it mainly depends on the eddy water which follows in the wake of a ship; which currents vary according to her run and the power exerted in propelling her, therefore no vessel ought to be given over by the builder or engineer until they have tried various pitches of the screw in order to obtain the best result.



The screw-propeller and shaft at an angle.
Fig. 18.

One of the difficulties which engineers and ship builders have to contend with at present in screw-propulsion is arranging the screws of sufficient diameter to resist the power required for high speed in light-draft ships. This I feel convinced could be accomplished by having the screw-shaft put at an angle of about 45° to the keel, which would allow the screw being made about one half larger in diameter than it is now in practice, of sufficient immersion, and of nearly double the propelling area in the same draft of water. I have made some experiments on a small boat worked by hand and obtained very good results. I had the boat prepared so that I could put it in motion when the same shaft was horizontal in the usual manner, as well as at an angle of 45° with another screw half as large as the former, and with the latter arrangement I had a far better result as far as could be judged by hand power, and I quite believe at some future period this plan as shown by the Fig. 18, will be adopted in preference to twin screws.



The action and form of a screw to produce negative slip.
Fig. 19.

Of late there has been much said as to what is generally termed "negative slip"—a subject which, after the following experiment, I considered was finally closed—but about which there still appears to be considerable diversity of opinion. In 1856, the steamship, *Flying Fish*, was fitted with a common screw of 20 ft. pitch, the engines made 76 revolutions per minute, showing a slip equal to nearly 20 per cent., which was considered a great loss of power. The Admiralty then ordered one of my screws and I was permitted to supply two sets of blades—the one pair fixed at right angles to the screw-shaft in the ordinary manner and the other pair cast from the same pattern, but set at an angle forward, towards the ship, as shown in the annexed diagram, Fig. 19; these angular blades when tried, gave a negative slip for the

screws, as I predicted, whilst the straight blades gave the slip equal to 20 per cent. loss, the speed of the ship being the same in each case with the same power exerted.

The negative slip was caused by the blades that were fixed forward, or at an angle with the shaft, driving the water past them at right angles, thereby acting on a greater surface or quantity of the back water than that, that was going forward to supply the space that the ship had just left—a better result as to negative slip would have been obtained were the draught of water sufficient to increase the diameter of the screw—a large diameter of screw with a ship of a full run, will invariably shew a negative slip; but a full run for a screw ship will not give the best result relative to the power exerted to propel her.

With respect to the application of twin screws, I never considered there could be any great advantages gained, except in two cases, the one, for manœuvring war ships during action, and the other, where the draft of the hull was too shallow to allow the screw to be of sufficient diameter in proportion to the power employed.

CHAPTER V.

THE GEOMETRY OF THE GRIFFITHS' SCREW-PROPELLER.

BY N. P. BURGH.

AS this propeller is merely a portion of a common screw, with the blades bent and shaped according to the ideas of the inventor, the principles on which it is founded must be as those illustrated in Plate 1 by Fig. 3; there it will be seen that the pitch, circumference, and helical line form a right-angle triangle, and it must be strictly understood that each portion of the triangle bears a definite relation to the whole, so that if the pitch is one, the helical line and the circumference are two, or the total must be three, thus the three elements are in unity with each other. Starting then with this axiom, suppose we require to demonstrate its purpose practically, *i.e.*, to produce the angle of the blade of a propeller in the absence of the ordinary geometrical method, the method available will be thus: raise from a point a perpendicular line equal to any portion of the pitch agreed on—say one-tenth—from its *lower* extremity produce a line at right angles equal to one-tenth of the circumference; join with a line the *upper* point of the vertical line and the outer end of that horizontal, which angle is that of the portion of the top edge of the blade, as seen in plan directly.

If a reverse angle for the blade is required, the vertical line of the right-angle triangle will be connected angularly at the *lower* extremity and with the horizontal line at the *upper*, as depicted by Fig. 3 in Plate 1, where A, C, is reverse to B, C^1.

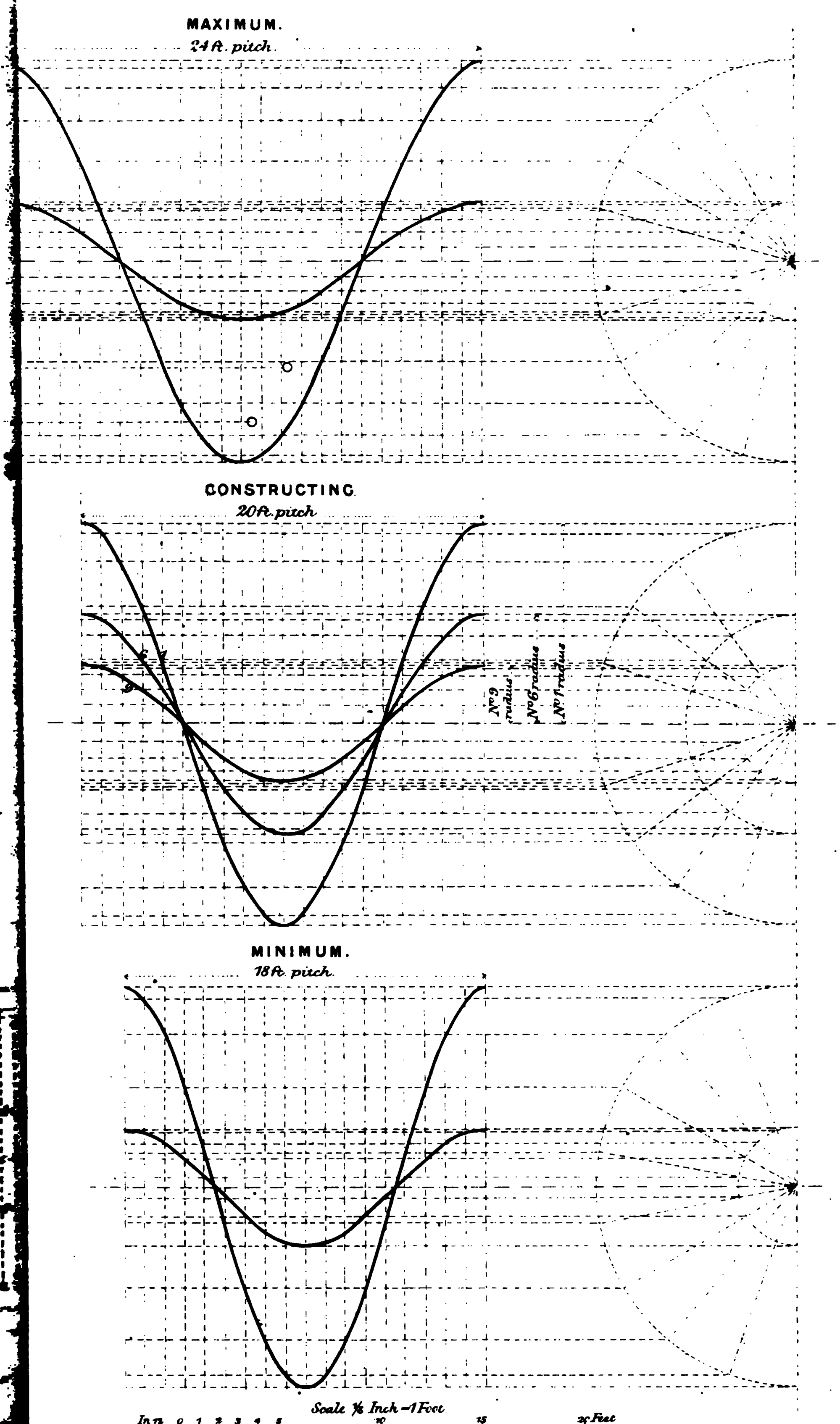
Having proceeded thus far, our next step is in relation to the form or angle of the blade from the top edge to its root or its connexion with the boss. Now, as the twist of the blade is due to the diameter and pitch of the screw, so will the method of producing the angles depend. Returning again to the assumed right-angle triangle, we presumedly notice that the horizontal line is a portion of the circumference of the diameter of the screw, hence it bears a conclusive relation to the length of the blade from the centre of the boss. But our present purpose is to ignore the boss and treat of the length of the blade from the boss to its top edge only; determining, next, the radius of the diameter of the boss, from that point the blade is divided into, say, six divisions. Similarly also, but proportionately,

the horizontal line is divided; then from these divisional points lines are drawn to the obtuse apex of the triangle, the angles of which are those of the various sections of the blade at the points of division on its length. But it may be urged in contradiction of this method, that the form of the blade of a true screw-propeller at the various points alluded to, and throughout also, must partake of that of the geometrical curved helical lines and therefore not of the straight or angular elements. This fact, however, presents itself in answer, that as the curves of the blade are actually of such short lengths of the helices in practice, the approximation from the angular lines are perfectly admissible for projection as a drawing, and indeed if the truth of this conclusion requires support, refer again to Fig. 3, Plate 1; raise the angular line B, C^1, to the curved helical line of the screw and it will be seen that the direct angle between the lines 3 to 5 is precisely as B, C^1, showing also that, that the portion of the blade could be faithfully depicted without the helical curved line, as far as the angle is concerned.

Having then proved the veracity of the triangle we now proceed with its application, commencing, of course, at the beginning of the mode requisite to delineate an example of the propeller under notice correctly. The illustrations introduced for this purpose are shown in Plate 7, the actual proportions of the example being, diameter of screw 20 ft., constructing pitch 20 ft., minimum 18 ft., and maximum 24 ft., diameter of boss 5 ft. 9 in., length 4 ft. 3 in., width of top of blade, 2 ft. 11 in., maximum width 6 ft. 2 in., and width over boss 5 ft. 3 in.

The mode of delineation is thus: the circle denoting the boss is drawn, next the outline of the flattened surface of the blade, the length of which from the boss is subdivided and cross-sectioned, as shown. The vertical section is next drawn, showing the curve of the blade, or the "lean-to" forward, the amount of lean-to from the back surface being 13 in. in this case. We have now the main elements of the blade depicted—in dotted lines—and as far as the actual construction is affected sufficient for all practical purposes; but the representation of the blade in plan and elevations requires additional delineation, which we will now describe. The constructing pitch of the blade at the edge and root is 20 ft., and the helical lines are produced by the ordinary geometrical method, also those for the 24 and 18 ft. pitches similarly, but in this case at a reduced scale to economise space. Having then the helices of the blade for construction, we commence to draw the plan at that pitch, as from it, and it only, must the elevations of the blade be produced. Now, as the sides of the flattened form of the blade on each side of the vertical centre line are duplicates or equidistant at all points, the centre line of the boss is the starting point for the plan. The lean-to of the blade from the centre line is equal to a^1, in the side elevation, then with a^1 as a radius and the centre of the boss as a centre describe an arc, which depicts the amount of lean-to in plan also. Our next step is to produce the angles of the blade from the last point or the top edge to the root.

N.P. BURGH.



Newbery & Alexander lith. 43, Castle St Holborn

Here we must reiterate the practicability of our remarks at the commencement of Chapter III., and also at the present one. We stated, to begin with, that the screw is merely a right-angle triangle, and we have added since—in this Chapter—that each portion of the triangle is in perfect unity with each other; so that any triangle, within the main or largest triangle, of the same proportions, will accomplish similar results as the larger in the matter of geometry.

Now, to test this again, the constructing pitch in this case is 20 ft., the diameter of the screw 20 ft.; then $20 \times 3{\cdot}1416 = 62{\cdot}832$, or the circumference of the screw, which produces a right-angle triangle whose height is 20, and horizontal line 62·832. Now, if we make a triangle whose height is 20 in., it will be $\frac{1}{12}$th of the larger, or the pitch in inches instead of feet for the height; the horizontal line will be 62·832 in., and the angle of the helical or angular line will be as that for the larger figure.

It is often the practice with engineers to simplify the matter in question by making the horizontal line one-fourth of the diameter of the screw when the vertical line is in inches of the pitch in feet, as we have done in the present illustration, which really is but a fraction short of the full horizontal line; consequently, the angular line is but scarcely affected by the variation. The main object for this concise approximation is that as one-fourth of the diameter of the screw is used for the horizontal line, all divisional spaces on it will be exactly one-half of those on the length of the blade, which renders the proportioning of the dimensions an easy method.

Having now settled the proportions of the right-angle triangle, we next proceed with its construction, and afterwards with the application. At the right hand of the side elevation of the screw in Plate 7 is shown the diagram of the constructing triangle, whose actual height is 20 in. and its length 5 ft., or one-fourth of the diameter of the screw. The elevation of the blade must now be referred to, as it bears special relation to the triangle. The half diameter of the screw is divided into certain spaces or divisions in the following manner: From the horizontal centre line of the boss set up the height, A, which is the commencement of the blade; from this point set up B, which is the top of the boss. The blade may now be divided into equal spaces, if preferred; but in the present case it is not, for reasons which will be explained as we proceed. From B set up C, which is a starting point to draw the first horizontal section of the blade, the remaining portion being sectioned at equal distances to and from the extremity. At the point C set up the equal distances, D, E and F, G, H, I, and K; the space F bears reference to the outer radius of the lean-to of the blade only. The horizontal lines 1 to 10 are next drawn, which divide both of the elevations alike respectively.

We have now to remember again that as the half diameter of the screw is double the length of the horizontal line of the constructing triangle, therefore all the divisions on that line must be half of those in the elevation of the blade, as depicted by the corresponding

letters and figures. From these points lines are drawn to the lower or obtuse apex, thus forming a series of right-angle triangles within the largest outline. We have now actually constructed the angles of the blade for the plan at the points of division in the elevation, or the same in principle as for a series of screws of unequal diameters, but of the same pitch; and our next purpose is the application of our attainments. Referring again to the plan, we started at first with the radius, a^1, and we must now describe the lesser radius, b^1, in the opposite direction—taken from b^1 at the root of the blade in the side elevation—which produces the limit of the lean-to of the blade from the back surface to the front inner edge. The utility of the "constructing right-angle triangle" now requires demonstration, and, to commence with, the angle No. 10 is available. This angle is laid on the plan as a tangent to the smaller curve, whose radius is b^1, the length of the angle being taken from the width of the blade at No. 10 in the side elevation; and as it is equidistant on each side on the centre line in that view, its extension corresponds equidistant also in the plan. The vertical line of the triangle is then raised from the point on the arc, which is the centre of the length of the angle 10; next the horizontal line is drawn equal in length to the original, and this line is also similarly divided, and their corresponding angles are produced, each extending beyond the apex of the triangle equidistant from that point on each side, the total lengths being taken from those in the side elevation numbered respectively 10 to 6. Now, if we turn to the side elevation of the blade, we shall see that the radius of the curve or lean-to commences at the divisional line No. 6; so that the vertical line of the blade's section terminates there also. Obviously, then, in relation to the plan, the utility of the right-angle triangle is concluded when in its present position. The angle No. 5 is now drawn, which very nearly intersects with the apex of the triangle, the length of this line being of course due to that corresponding in the front elevation. Next the angle No. 4 is projected, which, as No. 5, is also parallel from that in the triangle, and forms a tangent to an arc whose radius is taken from the lean-to in the side elevation at the divisional line No. 4; and the length of this angle is set off equidistant from the point of intersection on the arc, taken from the width at No. 4 in the front elevation. No. 3 angle is now produced in the opposite direction from the centre of the boss, but at the same angle of course as No. 3 in the triangle, an arc being described from the same centre as before with a radius taken from the line No. 3 in the sectional elevation, to denote the point of division for the length of the angle No. 3. The angle No. 2 is next projected from the triangle, its position in plan being taken from the lean-to in the elevation as before; and the utility of the arc and its intersection for the point of division is again observed. Lastly, the No. 1 angle is drawn on the respective arc of the largest radius, its length being of course equal to the width of the top edge of the blade, and its position from the boss due to the lean-to in the side elevation, as already mentioned. These several points are then joined by an irregular curve, as depicted, which illustrates the plan

of the blade from the root to the top. As all the divisional and constructing lines are figured alike respectively in the three views, the student can readily distinguish the angle of the blade at these points without doubt or confusion.

It is preferred in some instances to produce the angle of the blade at the root in the following manner; which we have also illustrated, at the right hand side of the plan, under the side elevation and constructing triangle: describe a circle whose diameter is equal to that of the boss; from the centre set off on the horizontal centre line, already drawn, a distance equal to one-fourth of the constructing pitch of the screw, divide this length into any number of divisions equidistant, say ten, as in the diagram; bisect the horizontal line on the opposite side in a similar manner to the circle's limit; next from the intersections on the line draw right angles lettered *z*, *y*, *x*, *w*, *v*, respectively on each side of the vertical centre line which is lettered *u*. Continuing now the horizontal line for a certain distance beyond the diagram already constructed, we next draw a semicircle whose radius is equal to that previously used; the arc is bisected by the horizontal line, and from that intersection on each side, one-fourth of the semicircle is divided into five divisions equidistant, making ten as a total as those on the horizontal line. From the intersecting points on the arc or semicircle, radial lines are drawn to the centre, and lettered *z*, *y*, *x*, &c; then with the vertical line *z* as a radius, and the centre of the semicircle as a centre describe arcs on the radial lines *z*, *z*, next with the vertical line *y* as a radius, and the same centre as before, describe second arcs on the radial lines *y*, *y*; the vertical lines *w* and *v* are similarly and respectively used, and as the lines *u*, *u*, in each case are centre lines, their position is unaltered in application: now from the latter intersections on the radial lines produce parallel horizontal lines, each respectively connected with the vertical lines above and below the central horizontal line, then a line drawn through these intersections will denote the angle and twist of the root of the blade at the boss, which is actually the same in principle as that depicted in plan from the constructing triangle.

The student must now direct his attention to the formation of the helical lines for the minimum, constructing and the maximum pitches, which are illustrated at the right-hand extremity of the plate; the minimum pitch being 18, the constructing 20, and the maximum 24 feet; showing a difference of two feet in one direction, and four in the other, producing therefore a mean pitch of 20·666 ft., which has been purposely omitted in the present case as the constructing pitch. Commencing now with the description of the delineation of the maximum pitch of 24 ft., it is first set out at a scale of $\frac{1}{8}$ of an inch to equal one foot—to economise space as before stated—a semicircle is then drawn whose radius is equal to the half diameter of the screw; the arc is divided equally into twelve divisions, and the pitch into twenty-four; the horizontal and vertical lines are next produced and the helical line of the top edge of the blade is formed by that line cutting

the intersections. The semicircle denoting half of the boss is then drawn, and radial lines produced from the intersections on the outer arc to the centre; where these lines cut the boss circle are starting points to project the horizontal lines from, which lines must be prolonged throughout the pitch, the helical line is then drawn, and from it and that previously constructed, the two angles of the blade at the root and the top edge are faithfully depicted at the pitch under notice.

Our next purpose is the mode of producing the constructing or helical line for the blade, at 20 ft. pitch; as a matter of similarity, and for no other purpose, the semicircle is divided into ten divisions, to agree in number with those on the blade's length, the pitch is divided into twenty spaces, and from this proceeding the helical line of the top edge of the blade is produced. Next we require the helical line or angle of the blade at the divisional line No. 6 in the elevation, as at that position the lean-to of the back of the blade commences; consequently all sectional angles above that point *cannot* cross each other on *one* point of intersection. The second semicircle is next drawn, whose radius—by scale—is from the centre of the boss to the divisional line No. 6 in the elevation of the blade; radial lines are then drawn from the outer arc to the centre, which, cutting the second arc—of No. 6 radius—produces starting points for horizontal lines to be projected. These latter lines cut those vertical within the length of the pitch, and through the intersections thus formed a helical line is drawn, which is that for the blade at "No. 6 radius." The mode of producing the angle of the blade for "No. 9 radius" is, of course, as that for the angle of the blade at the boss, the radius being similar in each case.

Now, the utility of our latter demonstration, although perhaps apparent to engineers, may not be equally clear to students; therefore, if we dilate a little on the subject, our purpose will be understood. Returning to the three angles of the blade at 20 ft. pitch, we wish to compare them with those similarly numbered on the constructing triangle. Now, if we use two set squares for this purpose, it will be the simplest method, thus: project the angle No. 1 of the helical line near to the angle No. 1 of the constructing triangle, and those two lines will be parallel; therefore, if the former line is laid on the latter, they will fit without overlap, as far as the angles are concerned. Next project the helical angle, No. 6, on to the constructing angle No. 6, and a similar result as before will occur; and, lastly, No. 9 helical angle will be found to agree also with that of the triangle. The student has now been again instructed as to the veracity of the diagram Fig. 3, in Plate 1, which, as we said before, is the basis of the principles of the screw-propeller; demonstrated also by the diagram in Plate 3.

The helical lines for the 18 ft. pitch are produced by dividing the semicircle into nine divisions, and the pitch into eighteen, the intersections of the horizontal lines forming the paths for the helices.

So much for the plan of the blade and the various means for producing it; we must

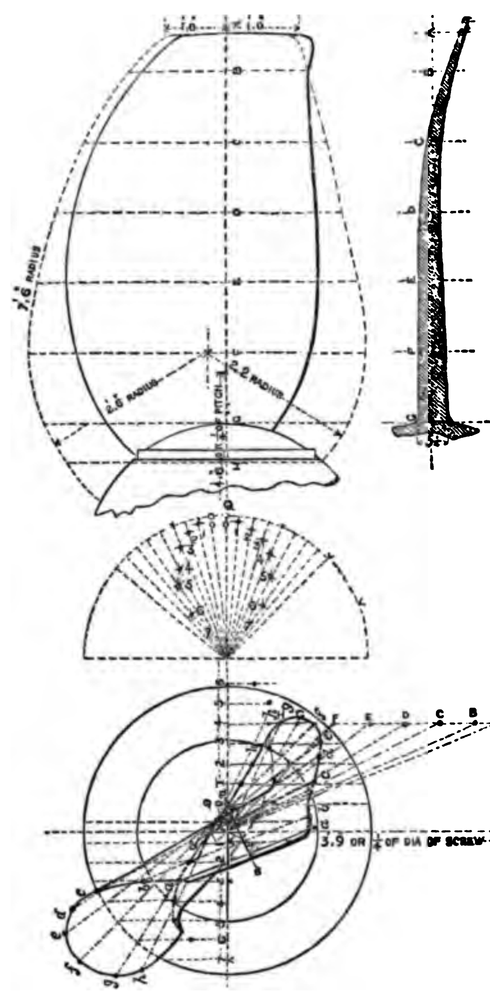
next describe the mode of forming the complete elevations of the blade, commencing with the front view. Now, as the plan is complete, from it we must project the front elevation, therefore from the edge of the blade, at the point of the angular intersections, draw vertical lines; connect these respectively on each side of the centre line with horizontal lines, which are lettered in alphabetical order from *a* to *k*. These lines, it will be noticed, are in strict relation to those on the elevation of the blade; therefore with *a a* from the plan as radii, and the vertical centre line as a centre, describe arcs cutting the line 1, or the top of the blade, which are the starting points; then the lines *b b* are used as radii on the line No. 2, next *c c* on No. 3, and so on in due relative order until the lines *k k* are used on the line No. 10, which terminates the projection. Lastly, the curves are drawn through the arcs on the horizontal lines, and thus the elevation of the blade is formed from the angles on the plan.

Turning next to the side elevation the method is the same in principle as before; horizontal lines are projected from the angular intersections in the plan, vertical lines connect them, which are lettered *a* to *k* alphabetically. The main feature here to be noticed is the centre line and its relation with that in the elevation and plan; then with *a a* as radii from the plan, and the intersection of the horizontal line, No. 1, with the vertical centre line as a centre in the sectional elevation, describe arcs cutting the line No. 1, on the same side of the centre line as in the plan, next with the radii *b b* apply them relatively on each side of the centre line of the elevation on the horizontal line No. 2, then *c c* on No. 4, and *d d* on No. 5, and continue to the end in alphabetical and numerical order. Through the arcs describe the lines denoting the fore and aft edges of the blade, which depicts the side elevation of the blade when set at a pitch of 20 ft.

It will be remembered that the sides of the flattened form of the blade are equidistant on each side of the centre line, the radii being 10 ft. for the top arcs and 3 ft. for those connected with the boss. It appears also in the plan, that, although the flattened form is equidistant on each side of the centre line in the elevation; in that view from the centre line a perfect inequality of position of the outline occurs; for instance, the radii *a* to *k* horizontally are all unequal in length, then again *a* to *k* are unequal vertically also; next from the centre of the boss all the points of the termination of the angles are non-equidistant from it; so that the starting points for the setting out of the outline equidistant are especially due to the intersections of the angles with the arcs of position, and also to the points of intersection at the root which has been described before in detail.

Now, it sometimes occurs that the flattened form of the blade is unequal on each side of the centre line of the boss in the elevation, and also that the arcs forming the sides are of unequal radii throughout; so that it presents a different aspect to that just described. Knowing this, and knowing, too, that it affects the geometry in a figurative sense—but not the principle—we have introduced the Diagram, Fig. 20, on the next page, as an example.

The diameter of this propeller is 15 ft., the minimum pitch 15 ft. 6 in., constructing or mean pitch 18 ft., and the maximum pitch 20 ft. 6 in. The geometrical delineation of this example commences with drawing the vertical centre line of the boss, then the horizontal centre line, not seen; and on the intersections as a centre, with the half diameter of the boss as a radii, the arc of the root of the blade is drawn, below which the flange for its connexion is produced. Next the limit or line of the top edge of the blade is set out from the centre of the boss equal to the half diameter of the screw, the length of the blade dating from the flange and ending at the top edge. The half width of the top of the blade is then set off equidistant, in this case, on each side of the centre line; next are set out, from the arc at the root, the equidistant divisional points G, F, E, D, C, and B; then draw the horizontal line, F, which intersects with the centre line of the boss, at this intersection as a centre, and, with 3 in. as a radius, describe an arc, or mark a point off towards the left hand, which, where cutting the horizontal line, is the centre of the unequal radii of the lower arcs or edges of the flattened form of the blade, as depicted, 2 ft. 6 in on the left and 2 ft. 2 in on the right hand. The arcs thus described extend only from the horizontal line, F, to the boss. The largest arc of 7 ft. 6 in. radius is then drawn, which connects the top edge of the blade and the arc of 2 ft. 6 in. radius, the opposite limit being connected by a curve and a straight line from the arc to the top edge of the blade. Having settled the geometry of the flattened form of the blade, we next direct attention to the sectional elevation at the right hand of the first view; the straight portion is raised which extends from the root to a point a little distance below the divisional line, D, and from it a horizontal line is projected equal to the radius of the lean-to of the back surface of the blade; the radius of the inner arc is then drawn, and thus the section is produced from the root to the top; the horizontal lines of division are then drawn through the respective points in each elevation, with the additional line, H, below the flange in the front view.



Geometrical delineation of the Griffiths' Screw-Propeller.
Fig. 20.

Leaving now the elevations for the present, we next proceed with the method of producing the plan; the two circles representing the flange and the boss are first described; next the horizontal and perpendicular centre lines, then on the intersection as a centre, and half the thickness of the blade at G, in the sectional view, as a radius, describe an arc which is the limit of the back surface of the blade in plan. Having now the position of the aft side of the blade on an arc near the centre of the boss, our next endeavour is to attain the position of the top edge of the blade in the opposite direction in the same view, which is accomplished thus: with the lean-to of the top of the blade from the centre line in the sectional elevation as a radius, and the centre of the boss in plan as a centre, describe an arc below the horizontal line on the right, which is the other limit required. We require next, however, the angles of the blades at these two limits, which are produced either by "ordinary geometrical" means or by the "constructing angle;" supposing the latter to be preferred, the proceeding is as follows: from the centre of the boss set up a distance on the vertical centre line equal to one-twelfth of the pitch, or the pitch in feet expressed in inches, from this point project a horizontal line to the right whose length is equal to one-fourth of the diameter of the screw; from this limit draw an angular line to the centre of the boss, which completes the outline of the triangle, the height of which is, to scale, 1 ft. 6 in., and the horizontal length 3 ft. 9 in., then from the horizontal limit of the triangle lettered A, the points B to H, alphabetically, are depicted, the spaces between which being half of those in the elevation; the angular lines are next produced; forming thereby the angles of the several sections of the blade, at the respective points in the elevation. Knowing now the utility of the triangle, its adaptation is but a matter of simple parallel projection thus: from the angle F project a parallel angle *f f* forming a tangent to the arc, denoting the limit of the back surface of the blade. We must now allude to the elevation of the flattened form of the blade, and to the line F in particular in that view, as on this line is the centre of the constructing radii 2 ft. 6 in. and 2 ft. 2 in. Now the distance of this centre from the centre line of the boss is 3 in., as before stated, which distance can be actually produced from the plan in this manner—where the angular line or tangent *f f* intersects with the arc and where it also intersects with the vertical centre line form two points, the space between them being 3 in.; therefore as arc and angle intersections in the plan form constructing points for that view, obviously they must bear a strict relation to the elevation; consequently, the space, 3 in., in plan is transmitted to the elevation for the purpose of construction there also. The angle G is next projected, forming *g g*, then H forms *h h;* we proceed now with E to produce the angle *e e*, and then with C for *c c;* afterwards with B to form *b b*, and lastly with A to produce *a a;* it is almost needless to state that all the angles which do not intersect at the point Q are tangents of separate arcs whose radii are taken from the sectional elevation. The next step is to produce the line

$a^1 a^1$, which is drawn at right angles to the angle $a\,a$, and intersects with the centre line at the point Q; the position where $a^1 a^1$ cuts $a\ a$ is the starting point to depict the length of the angle of the top edge of the blade, the distance being 1 ft. on each side, it being taken from the elevation where it is figured. The limits of the other angles are also taken from the elevation and are then set out on each side of the intersections at the point Q, and with the respective arcs, or if preferred a line drawn from Q to a^1, on the centre of the edge of the blade, will depict the points of division, and will directly correspond with a line drawn from the centre on F to the point A in the elevation.

We thus have demonstrated the fact that the plan can be produced in the most simple manner without helical geometry, as we have already explained; but before leaving that view we may as well describe the utility of the diagram directly above it which is for the purpose of "obtaining the angle of the root of the blade at the boss," also depicted in Plate 7; for the present application it is to start from the point Q in the plan, and set up 4 ft. 6 in. to scale, or one-fourth of the constructing pitch; this length is divided into sixteen parts—in the present instance, but any greater number will be equally, if not more available—the points of division are then numbered 0 to 6. Next, downwards similar spaces are set out and the points numbered beyond Q, from 0 to 7; horizontal lines are then drawn which extend to the outline of the diameter of the boss. The dotted semicircle is then drawn—equal to the half diameter of the boss—and the starting point of division is at Q, or the intersection of the vertical line with the arc. Now, if it is remembered that the position of the centre of the radii on the line F, in the elevation, is due to the set-off taken from the plan, it will be appreciated that the same cause applies for the blank divisional spaces in the plan and on the semicircle under direct notice marked Q to 0 in each case—it may here be added that the direction of these spaces are in strict connexion with each other. The semicircle is then divided into four equal parts, and the space on each side of the vertical centre line Q, is subdivided into eight divisions, which, added together, equal the total number of the spaces on the vertical line—that is equal to one-fourth of the pitch. As there is a blank space from Q in the plan, similarly there is a blank space in the semicircle, which produces nine divisions on the left hand in that view. The radial lines are next drawn, and the respective points marked thereon with radii taken from the plan; thus the radius of No. 1 on the left is the horizontal length of No. 1 in the plan below the centre line, and No. 1 radius on the right is from No. 1 above the point in the plan. Similarly all the other points are produced from the respective sources. Each point is then projected on to the horizontal lines; a line drawn through the intersections forming the angle required. Assuming now that all the angles are obtained, either by the triangular or the circular process, the limits of the blade are then joined by a curve, which forms the outline, as depicted.

The plan being now complete, we must next explain its use to produce the complete

elevation of the blade, at the angle or pitch it is now set at. The mode of obtaining this outline is but a matter of direct simple projection, which is rendered particularly so by the same centre line being available in each view as a starting point. Commencing at the root of the blade on the right hand, we use the horizontal distance from the centre line to *h* in the plan, above the central horizontal line, as a radius on the line H in the elevation; then the distance from *g* to the centre line in the plan is similarly adopted on the line C in the elevation; next the length from the centre line to *f* is used as a radius on the line F, also the length *e* on the line E; then *d* is used on D, next *c* on C, and *b* is used next on B, and, lastly, *a* on A; through these intersections a line is drawn, partly straight and the remainder curved as shown, which depicts the aft side edge of the blade. We next proceed to define the outline on the left hand, commencing at the top, or on the line A. It will, of course, have been noticed that to produce the outline already described all the radii have been taken from the right hand in the plan; and, further, that these distances are all above the central horizontal line; hence our present delineations are in a direct opposite direction to those previous. Starting again with the projection on the *left*, we use first the horizontal distance of *a* to the centre line in the plan as a radius on the line A in the elevation; next the length from the centre to *b* is described on the line B from the same centre line, after which *c* is used on D, then *e* is used on E; and, continuing in alphabetical order, the radii *f* to *h* are used on the lines F to H relatively, from the plan to the elevation; next through these intersections a curve line is drawn which depicts the forward side edge of the blade, as illustrated. The side elevation of the blade—not shown—on each side of the section is derived from the respective points on the plan, their distances from the centre line being taken vertically, and then applied horizontally in the elevation.

Now having defined the modes of producing the various views of two propellers of unequal proportions and form, our next purpose is to compare these attainments and dilate a little on the differences that occur in the outline of each view. Beginning then with the front elevation of the blade in each example, it is again noticed in Plate 7 that the flattened form is uniform on each side of the centre line of the boss; but in Fig. 20 an unequal outline is particularly observed; which although different in form does not affect the total area of the blade in proportion to the former example. The area of the blade in Plate 7, is the same on each side of the centre line because all the constructing radii are equidistant also; but in Fig. 20, what is lost in area on the right-hand by the contraction of the outline is made up by the extension on the opposite side; so that the required area of the blade is maintained. Next then as to the better form, for if with construction uniformity of outline is desirable it is well to preserve it if possible, and therefore not involve it with difficulties if they can be avoided; for it is obvious that the cutting off of the leading edge of the blade greatly curtails the acting area at that part, hence to retain the proper area throughout it must be put on below, either on the same side of the centre

line, or on that opposite. We must not overlook another fact also, that the construction of the blade is not always what we have intended it to be on paper, it often occurs that the outline is not exact, nor is the "lean-to" a true arc, but rather that both are irregular where regularity was intended—all of these latter remarks of course pertain to the construction mostly, but as the drawings under notice have been worked from, we have full licence to introduce a little practical queries in relation to them. The effect sought after with the form in Fig. 20, was to make the leading edge of the blade strike the propelling currents more smoothly than would presumedly occur with the ordinary or uniform shape; the idea, doubtless, being borrowed from the shape and effect of the oriental sword or "scimitar," which is curved back to render its duty more effectual. Now, as the full area of the blade for propulsion must be retained under all circumstances of design; and as with the form of blade in question the top is the narrowest portion throughout its length, therefore the "leading edge" is actually cut off or curved in the right direction; and also as there is no objection to making the trailing side a duplicate of the forward half, it really seems more a matter of caprice than the result of scientific research, to use the unequal form alluded to, viz., the bulging forward about midway, and contracting from behind near the top, to make up the propelling surface required.

We must next direct attention to the outline of the flattened blade in relation to its aspect as seen when set at the angle corresponding with the required pitch. Referring next to Plate 7, the "front elevation of the blade" shows that the dotted outline nearly encompasses that depicted by the full line, which latter illustrates the blade when set at 20 ft. pitch. The forms of the spaces between the two outlines are singularly unequal; the forward or leading side is entirely within the dotted outline, but the trailing portion is only partially so bounded; yet, notwithstanding this difference in position, the area of each boundary space are almost equal; for what is omitted in one place is made up by the excess in an opposite direction. Alluding next to the outlines of the blade in Fig. 20, it is apparent that although the flattened form is irregular, yet the encompassing areas between the outlines are nearly equal on each side of the centre line, not only in superficial contents, but in actual form also. We notice, on comparing the two views, that the flattened outline in Plate 7 is equidistant from the centre line of the boss; but when the blade is set at the angle required, the leading side presents a fuller curve or bulge than that opposite; similarly in Fig. 20, as there is a greater difference in the form of the fore and aft edges of the blade, there is a greater contrast in the appearance of the outlines with that in Plate 7.

From the preceding remarks and facts we may safely conclude that the form of the blade when set at the required angle, in the complete elevation, is the main consideration, and that the flattened form must depend on that outline when it is first determined, and not *vice versâ* as the practice in general; but this alteration will not in any

way affect the principle of the geometry; for it is as practicable to produce the flattened outline of the blade from the complete elevation as to reverse the mode of projection, or as with the method already explained. As a proof of this fact, we will assume that we require to produce the "flattened" form of the blade as a conclusion instead of as a commencement, or that we intend the form of the blade to depend entirely on its side and front views, and having settled either or both, we proceed to draw the plan, next the remaining elevations, if required, and, lastly, the outline of the flattened form. Turning again to Plate 7, as the best illustration for our present purpose, we commence with producing a central vertical line in the front elevation next the horizontal centre line of the boss, which latter is next drawn, and then the length of the blade set up; our next proceeding is to decide the outline of the blade in this view when set at the 20 ft. pitch, which we accomplish by drawing the curve line on the left as the leading edge, and that on the right as the trailing side.

Now, if we desire to cut off more of the leading corner than shown by the full line, we can carry out that idea by drawing a curve inclining more towards the centre line, and thus reducing the area at the top of the blade, which loss of space can be replaced about the centre of the blade's length if required.

Assuming, then, that the outline is to be as depicted, we next form the sectional elevation of the blade from its root to the tip, with the amount of "lean-to" agreed on; the half diameter of the propeller is next divided into the number of divisions lettered A to K, the horizontal lines are then drawn which are utilised to produce the plan. The mode of producing the latter view is to first draw the arcs of position of the several angles, the radii being taken from the sectional elevation as before mentioned; the constructing triangle is again employed, and from it the tangents are obtained; thus the tangents 10, 9, 8, 7, and 6, are all connected on the arc b^1 whose radius is b^1 in the section; the tangent No. 5 is projected from the angle No. 5 slightly nearer to the centre of the boss, the actual position or arc being known from the sectional view; the arc No. 4, denotes the position of the angle No. 4, then the arc No. 3, settles the position of the tangent No. 3, next the arc No. 2 defines the starting point for its tangent, and, lastly, the main arc of the largest radii No. 1, completes the projection of the angles from those of the triangle. Now, it must be strictly remembered that although all the angles are drawn, they are presumed to be of indefinite lengths at present, and the next process is to decide their several extremities; therefore as the horizontal lines of position in the front elevation are respectively related to those angles, their utility to define the plan from the elevation is obvious; and the angles, as they are now assumed to be are without any definite limit the real purpose at present is to determine how far they may, or may not extend. To accomplish this in the most effectual manner we must return to the front elevation of the blade and commence with the line No. 1; this line is projected

parallel on to the angle No. 1, which defines the length of the latter, so that the horizontal length of the angle is equal to the length of the line; the most concise proceeding is to square or project the limits of the lines on to the angles, which of course defines the lengths of the latter immediately, or if preferred the radii a to k can be used as before, but reverse in their application; it is obvious therefore that the plan can be as easily produced from the complete elevation as from the flattened view.

Our next purpose is to explain the method of producing the flattened form from the plan, but which is indirectly taken from the elevation. Having drawn the irregular curve through the intersections on the angles, the outline of the blade may be said to be complete. We next allude to the points of intersections on the angles between their limits, or those with the arcs of positions, remembering that those points separate the angles centrally of their lengths; then, as the angles are divided *centrally*, the outline of the blade, when laid flat, *must* be *equidistant* throughout on each side of the centre line also. Now, then, to prove this, which is readily accomplished by using half the length of each angle as radii to describe arcs on the lines in the elevation; with their intersections with the vertical centre line as centres; then a line drawn through these arcs on each side will define the flattened form of the blade of equal outline from the centre line of the boss.

The veracity of this method can be tested also with the diagram, Fig. 20; the flattened outline there is purposely unequal; similarly, also, the outline of the plan corresponds, inasmuch that the intersection of each angle with its arc of position is *not* centrally of its length; and as that intersection is the basis to form each view, the result as shown must naturally occur.

We will compare now the difference in the shapes of the plans of the two blades under notice, and, to render the matter concise and easily to be understood, the student must imagine that an angle is drawn across each plan near the centre of its outline, which we will term the "mean angle." It will be seen that the plan in the Plate 7 is actually equidistant on each side of the flange of the boss across the "mean angle" of its present position, which, of course, is due to the duplicate form of the dotted outline of the blade in the elevation; but, on turning to the plan in Fig. 20 a wide difference of overlap is seen across the "mean angle" of position; for on the right hand the outline of the blade extends within the limit of the boss, but on the left it overlaps the same to the required extent, much more also proportionately than in the plan in Plate 7; of course this difference is due to the peculiar outline of the blade in each example, which is uniform in one case and irregular in the other.

While on the present subject it will be well to direct attention to the fact, that the elevations and plans of the blades of the propellers under notice relate to the top blades only, and that the geometry for the lower or remaining blades is entirely reversed in its application. The student will perhaps comprehend this matter more completely if he turns his

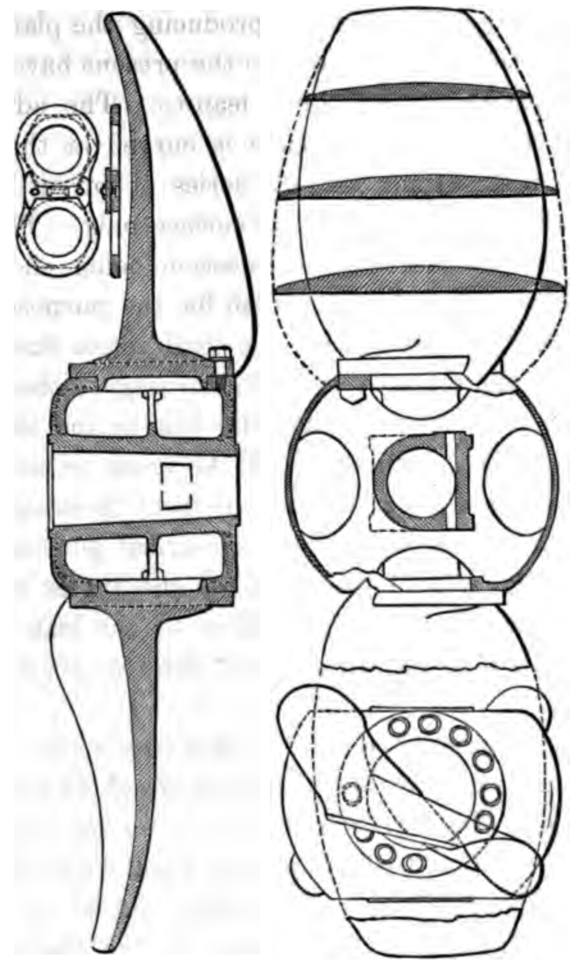
attention again to Plate 2, and particularly notices the plans of the top and bottom blades, as depicted by the diagram Fig. 8, where it is clearly shown that their positions are entirely due to the reverse application of the helices, so that, if with the example in the Plate 7, the plan of the bottom blade was required, the mode of producing it would result from the constructing triangle being situated exactly opposite, or on the left-hand, therefore all the angles of the lines of division would cross those already drawn in a contrary direction.

The front elevation also would be produced simply by a reverse repetition of the outline, for example, this view as at present illustrated shows the leading side of the top blade on the *left* hand; now if that blade is presumed to be reversed in its position, or the propeller turned towards the left hand on its axis for half a revolution, the leading side will be on the *right* hand, and the trailing half reversely situated also; or if the propeller were turned towards the right hand the leading side would be on the left, and the trailing edge opposite. So that when drawing the lower blade all that requires to be remembered in the main, is that it is the top blade turned downwards. Next, with reference to the side elevation of the blade, here it must be distinctly remembered that the propeller when turning on its axis causes the blades either to recede or advance, above and below the centre of the boss, from and towards the spectator, therefore *no change* of outline either to the right or the left occurs, then under all circumstances the same outline presents itself whether the same blade is up or down.

The peculiar form of the outline of the side elevation of the blade in Plate 7 contrasts widely with that in Fig. 8, in Plate 2, and the cause for this is that Mr. Griffiths has proved that there are great advantages in inclining the upper half of the blade forward which he accounts for in this manner, "that when the ship is under way the propeller is supplied with water from the after-current, and this current has to be turned from its natural course which is to fill up the space or channel that the ship has left and also to supply the screw with propelling resistance; so that when the points of the blades are bent towards the ship they meet this current and offer a certain resistance to the power employed to work the screw, or what may be termed a greater *bite* to propel the ship." By looking, then, at the outline under notice, and remembering the preceding remarks we shall readily understand that the right-hand side is the leading edge; which "curves forward" sufficiently, and in strict accordance with the other views to make the areas of the spaces on each side of the section to be nearly equal. We can imagine, therefore, what the effect of the "lean-to" would be if the example alluded to was revolving, for, as the leading edge is particularly formed to invite the currents into the hollow, that portion can grasp them more effectually than a straight blade.

Agreeing as we do with Mr. Rennie's remarks on page 9 of this work, that "after all the best and most useful information for an engineer is that which relates to the different

views and mode of construction," we have introduced the Fig. 21 as an example of recent construction, for our present purpose of further describing the geometry of the propeller under notice. In this illustration the sectional side elevation is shown on the left, the front view partly in section on the right with the complete plan below it; this example of propeller is much the same as that in Plate 7, the principal difference being that this, Fig. 21, is a "left-hand screw," while that in Plate 7, is "right-hand." The present example shows both the blades, with the relation of them conclusively depicted in the sectional side elevation; the forward side, below the boss, is very similar to that above the same in Plate 7; a family likeness is apparent also with the aft edges; for in each case the same form of outline is nearly represented. The front elevation shows both blades also; so that our previous remarks respecting the alternate change of the leading and trailing edges are clearly illustrated by this view — the full curve line being on the right above the boss and on the left-hand below it. Referring next to the plan, the outline of the top blade is shown complete, while the extremities of the sides of the bottom blade appear only beyond the boss; particularly noticeable also in this view, is the fact that the reverse angles of the blade are faithfully depicted, which strengthens our previous description of this matter.

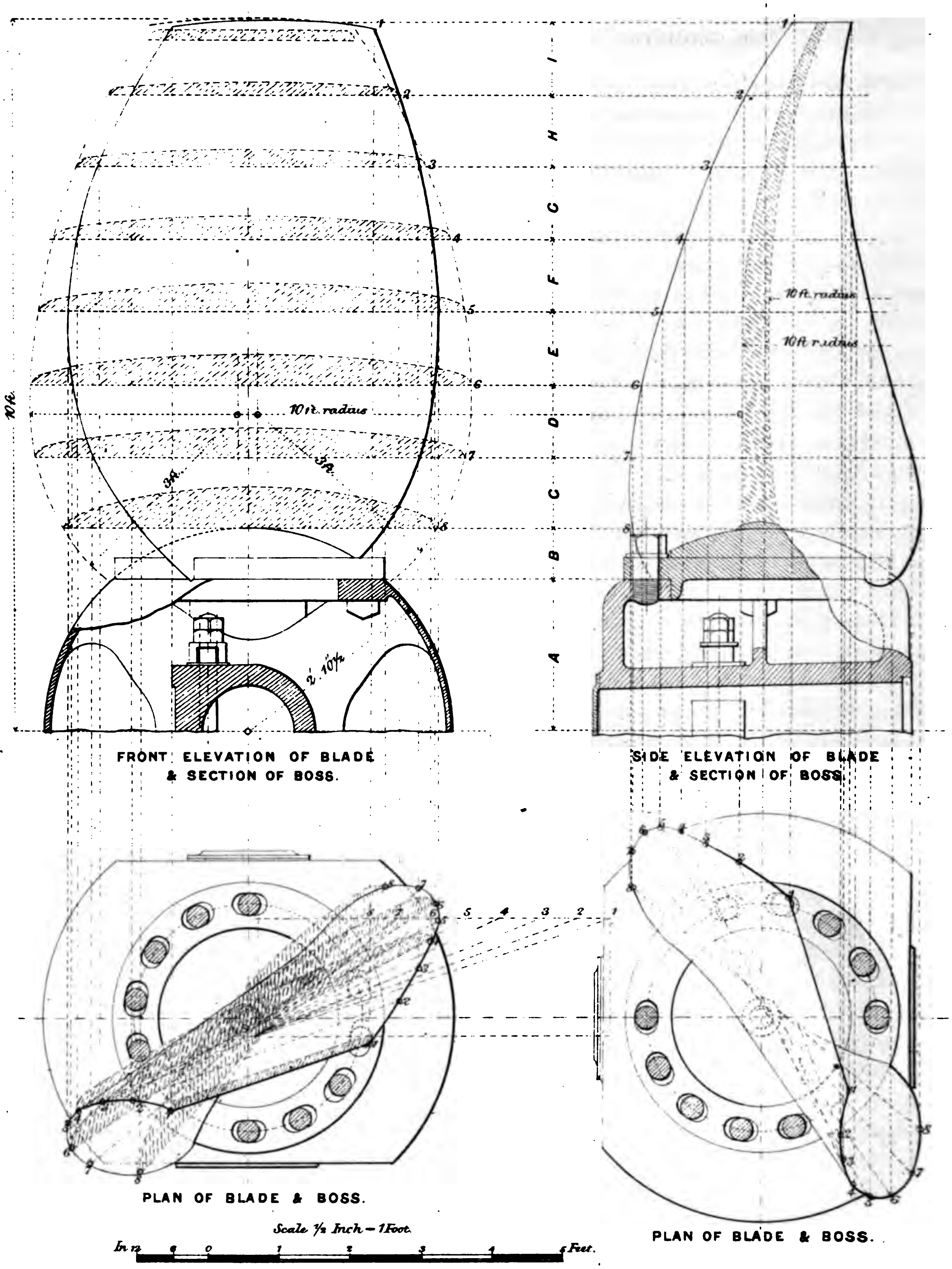


Modern Two-bladed Griffiths' Screw-Propeller.
Fig. 21.

The sectional portion shows the thickness of the blade and the amount of "lean-to;" the boss also is clearly shown, with the "key-ways" for securing the boss on the shaft. The blades are flanged at the roots, and the flanges are secured to the boss by studs and nuts; the latter are fitted with stop-plates to prevent looseness from the vibration that occurs when the propeller is in motion. One of these plates is represented in plan and section near the blade above the boss. The arrangement of the bolts can be seen from the plan, their position being on each side of the root of the blade.

Plate 7 A

GEOMETRY OF THE SCREW PROPELLER, BY N. P. BURCH.



FRONT ELEVATION OF BLADE & SECTION OF BOSS.

SIDE ELEVATION OF BLADE & SECTION OF BOSS.

PLAN OF BLADE & BOSS.

PLAN OF BLADE & BOSS.

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Harbory & Alexander lith. 41 Castle St. Holborn.

E. & F. N. Spon 48, Charing Cross, London

We now direct attention to the mode of producing the plan of the "front surface" of the blade, for our geometrical illustrations to the present have borne special relation to the "back surface," or from the back to the lean-to. The advantage of the geometry about to be explained, is that when the blade is curved at the back or thinner at the edges than in the centre, that surface forms a series of curves in the plan, consequently the angles of position must refer to the front surface only. The illustration, Fig. 21, is an example of this class; the sections in question being shown across the flattened portion of the blade. Now if we look at the plan for the purpose of defining its relation with the sectional elevation of the top blade, we shall notice that the lean-to in the latter view appears to hide the front surface; but on returning to the plan it is obvious that a portion of that surface must be seen, because the lean-to and the back surface are above it towards the left-hand. If we again allude to the cross section we shall readily understand that as the back portion is curved and the front is straight, or forming chords as it were, this latter portion is the better for geometrical purposes, although we may add that, by strict allusion to the arcs of positions, for the angles of limit in the plan taken respectively from the elevation, the back surface to the lean-to, can be made equally available as the limit from the front surface and the lean-to, to show the latter surface in plan.

The student may here again be reminded that the whole question is to be readily answered by remembering the geometrical principles, which we have fully explained without restriction on any point, but which we will enlarge on for the purpose of exciting further interest in the matter under notice. Starting again then, we will assume that it is essential to produce the drawing of a propeller of the class before us, whose proportions are precisely as those in Plate 7, and that the cross sections of the blade are fully curved at the back, also perfectly straight at the front, this example being illustrated by Plate 7A.

The method of producing the several views is to commence with the flattened blade; having formed this outline, the sectional elevation is then drawn with the lean-to agreed on, the flange of the blade is then formed in each view, and below this the boss; then in the front elevation where the flattened outline of the blade intersects with the curve of the boss is the starting point to draw the lines of division of the length of the blade, which distance from the centre of the boss is lettered A; from the limit of A upwards set out B, which is a tangent to the arc forming the boss. Now as the last point is the commencement of the vertical section of the blade, it is termed the root as before noticed, therefore from the root upwards to the top, the blade can be divided into equal divisions as lettered C, D, E, F, G, H, I; next on each point of division draw horizontal lines across the two elevations, which are the base lines of the horizontal sections, the central thickness of each being taken from the vertical section, and the thickness at the edges from proportions agreed on. Assuming now that all these sections are drawn as depicted

they are next numbered 1 to 8, also the divisions in the vertical section, to show their relation conclusively.

We have thus far described the flattened outline, the vertical and horizontal sections, and our next advance is to produce the plan to which we now refer. The constructing triangle is now utilised, its height being 1 ft. 8 in., and the horizontal length 5 ft., the latter being proportionately divided into the same number of spaces as the length of the blade, and thus the points for the respective angles are produced, being numbered as in the elevations. Next on the centre of the boss describe an arc towards the right-hand whose radius is half the thickness of the blade at No. 8 in the vertical section; then as the vertical line of the triangle must be parallel with the vertical centre line of the plan, and the angle No. 8 forms a tangent with the arc, it is evident that where the obtuse apex intersects with the arc is the position of the triangle. The remainder of the arcs are then drawn from radii taken respectively from the vertical section; the angles are used as tangents, and thus the starting points for setting out the outline are produced. The limits of the angles are determined from the outline of the flattened blade, and as that view is equidistant from its centre line, all the angles are equidistant also from their centres, which are the intersections with the arcs of position; the irregular curve is next drawn through the limits of the angles, which concludes the outline of the front surface of the blade in the plan.

We now have to utilise our accomplishment for practical purposes still further, which is done in this way. The angle No. 1 in the plan is that of the top edge of the blade, or the limit of the lean-to; hence we draw a similar section as No. 1 in the elevation on the respective angle in the plan, which shows thereby the angle and section of that portion at once in the same view. Similarly we make use of Nos. 4, 6, and 8, which portrays the angles of those sections in the most correct form; not only separately but respectively also.

We know now the angles of each section of the blade that we have delineated in plan, and we know too that these angles bear special reference to the elevations—not only to the flattened outline, but also to the vertical section—so that really we have the plan of the blade at four points, which is produced by geometry of the simplest order.

As we are dealing in particular with the surface of the front of the blade, it will not be out of place to describe how to produce the front and side elevations from the plan, to correspond with it; and thus we shall illustrate the relative outlines as they actually agree with each other. Commencing, then, with the front elevation, we project the limits of the angles on to the respective lines of division, and through these intersections the outline of the blade is drawn, which forms the view in question. To better enable the matter of projection to be fully understood, for all purposes, we have drawn another plan of the blade underneath the side elevation, which in that special position refers entirely to

that view; the proceeding, therefore, is as that previous, being merely; projecting the limits of the angles on to the lines of division and drawing the outline as depicted.

The advantage to be derived from the present matter is, that by a combination with the illustrations in Plate 7, and the descriptive matter attending it, a definite representation of the blade can be known under any circumstances. For example, in Plate 7 we have the outline, correct, of the back surface; in Plate 7A we have similar views of the front surface, so that by at once utilising both, if required, two views of two surfaces can be shown at the same time.

We next branch off to another subject which bears a firm relation to all our preceding remarks and illustrations, *i.e.* the length of the blade on the line of keel and the geometrical result affecting it by altering the angle or pitch of the blade. Now the first step is to decide at what position of the length of the blade the constructing pitch shall be altered into the varying pitch, either coarser or finer, as agreed on; for it must be remembered that the actual form of the blade is not affected in any way by the alteration of its position, so that if the blade is set at a known angle for a certain pitch, excepting the constructing pitch, that angle bears relation to the pitch of *one* position only on the length of the blade, and not therefore to the whole length or surface of it, which the constructing pitch and angle embraces.

As an example, let it be assumed that a propeller is constructed at 16 ft. pitch from the root to the tip, and that the two variable pitches extend from and to 12 ft. and 20 ft.—extreme proportions, but particularly adapted for the present purpose. Obviously, the angles of the top edge and the root of the blade are relatively unalterable, therefore if the blade is set at any other angle than that for the mean or constructing pitch, only *one* portion of the blade will agree with the pitch it is set at. Suppose, then, that the mean length of the blade on the line of keel is 2 ft. 3 in., the distance between the angles of the root and tip will be about 11 in., and these are fixed dimensions it must be remembered. It is agreed next that the top edge of the blade shall be set at the 12 ft. pitch, or relative angle; the result will be that although the top edge is at the pitch required, from that point the pitch is *decreasing*, and at the root it is considerably *less* than at the top; because both limits are moved and secured in the same direction. Next assume that the same blade is set at the 20 ft. pitch for the top edge; it will be apparent that as the blade is shifted in an opposite direction to that previously, the pitch at the root is considerably *more* than that at the top.

We have, therefore, proved from these conclusions that if it is desirable to have a mean difference of the pitch throughout the blade, when the top edge is set at the least or greatest pitch, its form must *not* be a portion of a true screw, but must be constructed from a series of pitches, the greatest being at the root; so that when the blade is set at the mean pitch a corresponding difference occurs, as in the other positions. This may be

termed an uniform arrangement, but as to its action in the water we need not allude to it for the present.

Treating now of the length of the blade on the line of keel, we know that if a blade is set at 16 ft. pitch, and is of a certain form, its length is 2 ft. 3 in.; we know, also, that if the same blade were set at 20 ft. pitch its length will be increased to 2 ft. 7 in.; and when set at 12 ft. pitch the length will be reduced to 2 ft., so that the side elevation of the same blade will depend entirely on the angle it is set at in the plan.

It is obvious from the above proportions that when the blade is turned or shifted on the axis of its flange *towards* the centre line of the boss, which is at right angles with the keel, the pitch of the screw is *reduced* and likewise the length of the blade on the line of keel. It is apparent also that by turning the blade in the opposite direction, or *from* the same centre line of the boss, an opposite result will occur—the pitch will be *increased*, and similarly the length of the blade will be affected.

Having thus settled all the matters in connexion with the geometry of the screw-propellor of any kind, we now direct attention to the following axioms on which the entire subject is based.

1st. The geometrical basis of the principle of the screw-propeller is that it is a right-angle triangle whose base line is equal to the circumference of the screw, its height the pitch and the hypothenuse the lineal length of the helical line.

2nd. That the $\sqrt{\text{pitch}^2 + \text{the circumference}^2}$ = the length of the helix of the screw —a matter admitted to be of universal knowledge but not of similar appreciation in connexion with the use of the screw-propeller.

3rd. The height, length, and hypothenuse of the triangle are in proportional unity with each other, although each are separate functions of the screw.

4th. As the height is the pitch, if any portion of the pitch is dispensed with, the height of the triangle is reduced accordingly, likewise the length, but the angle of the hypothenuse remains as before.

5th. The lesser triangle alluded to is termed the "constructing" triangle, and any other angles joining the horizontal line and the obtuse apex will be those of the sections of the blade at respective points on its length.

6th. The helices of any portion of the blade are precisely at the same angle for a certain length as the respective angle of the constructing triangle; the utility of the latter therefore dispenses with the formation of the former to produce the plan as shown in Plate 7.

7th. Any divisional lines on the length of the blade can be utilised in the plan and on the horizontal line of the constructing triangle, but in strict proportion as to position and dimension.

8th. The application of the triangle to produce the plan must be in connexion with

arcs of position whose radii are taken from the side sectional elevation of the blade, and the centre that of the boss.

9th. The intersections of the angles and arcs are the starting points to define the limit of the angles.

10th. The length of each angle on each side of its intersection is taken from the flattened form of the blade, or it can be squared from either of the complete elevations of the blade, provided the form is in unity with the flattened shape.

11th. For practical purposes the plan of the front surface of the blade should always be drawn from the flattened form of that surface, and the thickness of each section can be used to produce the plan of the back surface if desirable, also the complete elevations will be thus correctly shown as both surfaces are depicted.

12th. The area of the blade can be known from the constructing triangle, when the length of each angle is determined; as many angles as convenient can be used, and from them the mean width obtained, which multiplied by the length from the root to the tip equals the area required.

CHAPTER VI.

THE GEOMETRY OF THE PADDLE-WHEEL.*

By Mr. Charles Barclay,

of the Firm of Messrs. James Watt and Co.

THE annexed diagram, E, shows the curve traced out by a point on the circumference of a circle revolving on a plane. The point leaves the plane at A and reaches it again at B. A B is equal to the circumference of the circle. This curve is called a cycloid.

A somewhat similar curve is traced out, shown by the diagram F, by each of the floats of a paddle-wheel, the only difference arising from the fact that the wheel is revolving in a fluid instead of on a plane, the inefficient resistance offered by the water causing a certain loss of speed to the distance traversed by the centre of the wheel. This loss of speed is called slip. The curve may be understood better by this annexed diagram, F, which has been constructed as follows.

A wheel of the ordinary radial description having a diameter of 18 feet and 16 floats, one of whose floats is at A′ when the centre of the wheel is at O, is made to revolve in water.

Presuming there was no slip, at the end of a complete revolution, the float at A′ would have arrived at C′ where A′ C′ is equal to the circumference of a circle whose diameter is 18 feet, and O O′ (= A′ C′) would represent the advance of the centre of the wheel during the period of a revolution, or the advance of the vessel which is propelled by it. In consequence, however, of the slip which always occurs, and which in this example has been taken equal to 20 per cent., at the end of a revolution the float which commenced at A′ has only arrived at B′, and the centre of the wheel at O″. The path

* As this subject may appear a little out of place in this work, I may state that the cause for its introduction is that in no other work to the present has such an explanation of the matter been given, and it was for this reason Mr. Barclay kindly contributed this article and diagrams to supply the much-wanted information for the benefit of the profession.—N. P. B.

GEOMETRY OF THE PADDLE WHEEL.

· BY MR. C. BARCLAY.

DIAGRAM OF A CYCLOID.

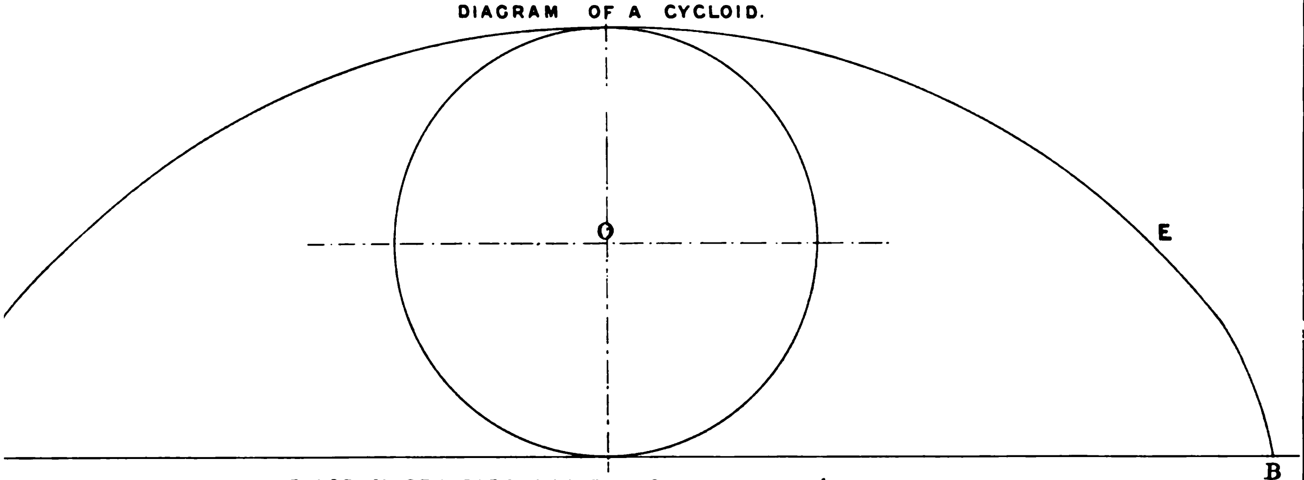


DIAGRAM OF A PADDLE WHEEL 18 FT DIAMETER 1/8 IN—1 FOOT.

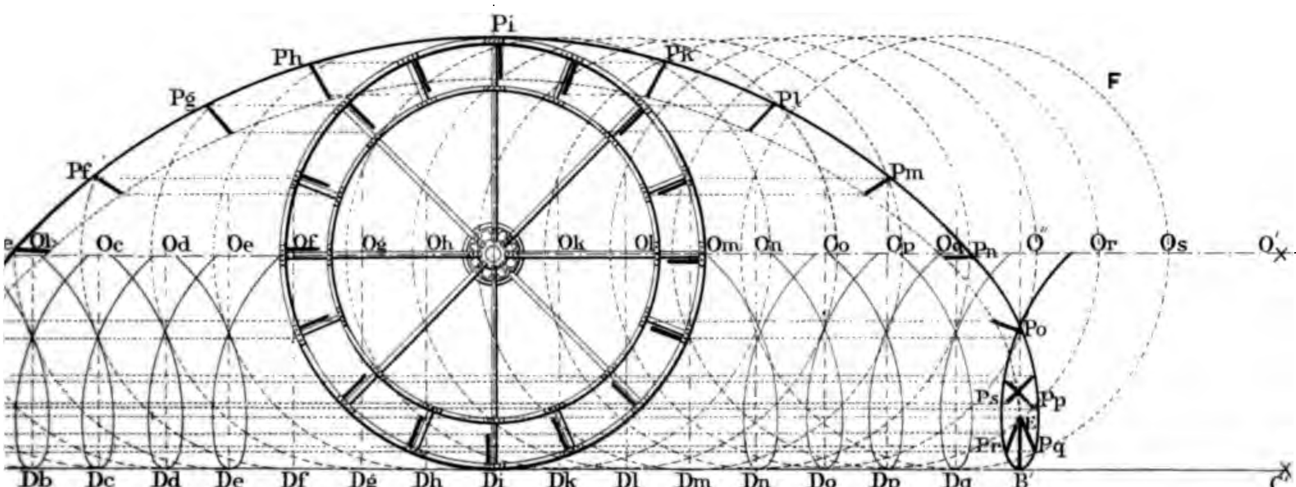
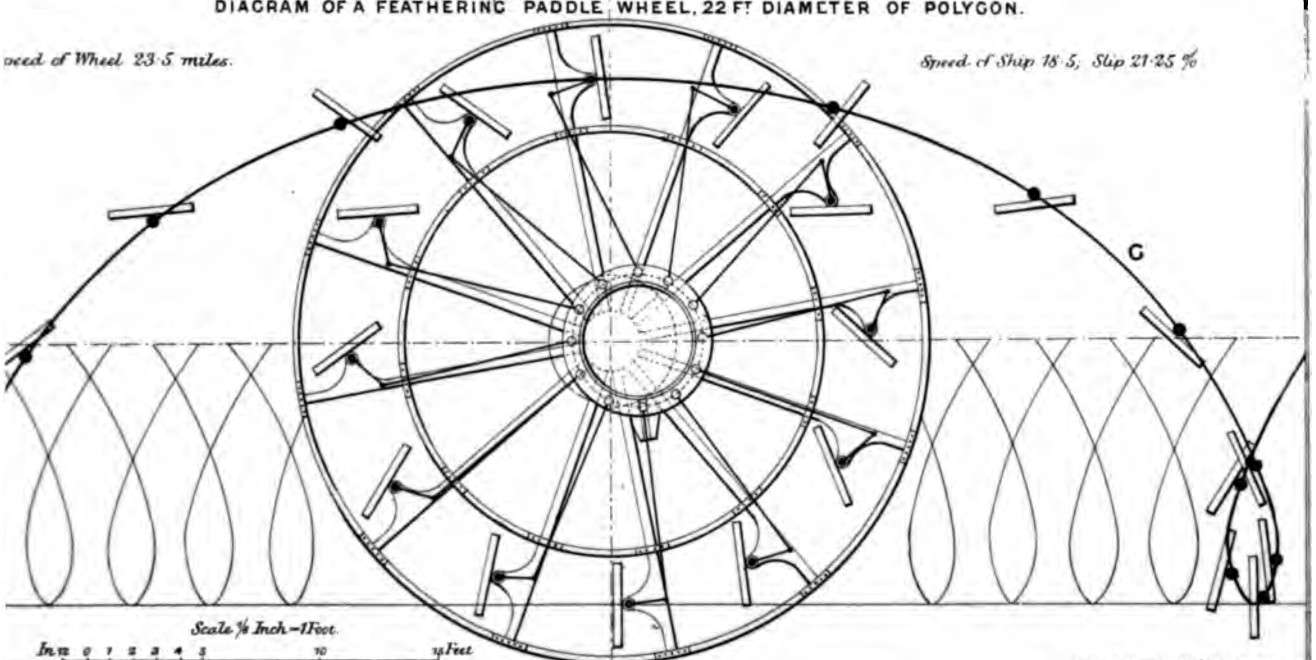


DIAGRAM OF A FEATHERING PADDLE WHEEL, 22 FT DIAMETER OF POLYGON.



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traced out by the float is represented by the curve $A' P_b P_c \dots P_q B'$, which is thus constructed : divide $O O''$ in any number of equal portions, sixteen in this example, viz. $O O_b = O_b O_c = O_c O_d = \dots = O_p O_q = O_q O''$; and from the points $O_b O_c \dots O_p O_q$ as centres describe circles with a diameter equal to the diameter of the wheel.

The circles are represented by the dotted lines $D_b P_b$, $D_c P_c$, . . , . ., $D_p P_p$, $D_q P_q$. Divide the circumference of one of these equal circles into sixteen equal segments, of which $D_b P_b$ will represent one, or a sixteenth part of the circumference, and mark on the circle whose centre is O_b a segment equal to $D_b P_b$, and on the circle whose centre is O_c a segment equal to twice $D_b P_b$ or $D_c P_c$, and so on, so that $D_p P_p = 14 D_b P_b$, $D_q P_q = 15 D_b P_b$; $P_b P_c \dots P_q P_q$ represents the position of the float when the centre of the wheel is at $O_b O_c \dots O_p O_q$. A line passing through these points $A'. P_b. P_c. \dots P_q . B'$ represents the path of the outer edge of the float; if the curve traced out by the next revolution of the float be drawn, viz. $B' P_r P_s$ the slip of it in its passage through the water will be represented by the loop $P_o P_p B' P_2 P_s$. The slip of the preceding floats are shown by the loops traced out at points $D_b . D_c . D_d$, &c. This diagram also shows the position of the float and the angle it makes with its path at different periods of the revolution.

A dotted line is also drawn showing the curve traced out by the inner edge of the float, which has scarcely any slip, only that represented by the very small loop at E.

A diagram, G, also of a paddle-wheel with feathering floats is annexed, where the slip was 21 per cent. This is taken from an experiment were the duty was purposely recorded. This diagram is constructed in precisely a similar way as in the example of the radial wheel, without the addition of the dotted lines, so as to make it clearer.

It may not be out of place to state that the object of a feathering wheel is to cause the floats to enter the water nearly vertically, while preserving the vertical position of the float at its lowest point, as in the radial wheel.

CHAPTER VII.

A DESCRIPTION OF MODERN SCREW-PROPELLERS CONSTRUCTED BY THE MOST EMINENT MARINE ENGINEERS OF ENGLAND AND SCOTLAND.

BY N. P. BURGH.

INTRODUCTION.—There is undoubtedly a great deal of practical information in mechanics to be derived from examples of actual construction which are rendered by their effective duty standards of references. As to the principle of this it applies to every class of mechanism; for when the result of the duty is known, be it good or bad, the detail or machine is considered an example of importance, as a reference, either to copy or avoid as the case applies. Much benefit is to be gained also by consulting a number of examples of the machine or detail where each is performing the same purpose under different modes of application; but the results nearly alike. In a contrary way the engineer gathers information from unequal results of duty, although the class and position of the mechanism may have been as before stated.

As applied mechanics are really but the application of detail for certain purposes, our previous remarks refer also to screw-propellers; and the force of our argument is strengthened by the fact that to the present no two sister ships, stated to be duplicates, attain the same speed. From this fact we are naturally doubtful about our actual knowledge of the subject, for it occurs—that, if we have two hulls, two sets of engines, boilers, and propellers, weights on board, and immersion, duplicates, yet, after all these precautions, we find that the speeds of the ships are *different*, when really that result was the main purpose we wished to avoid, we have therefore the evidence of a mistake somewhere; for, in our endeavour to cause an *equal* result, we miss the mark. Now there is not the same difficulty in making the actual speed in advance of the estimated speed; for we have only to arrange certain matters in connexion with the formulæ, and the result is readily acquired for a single example; but when we have a duplication to deal with, and the formulæ the same, our failings are apparent. The fault on our part is not

that we do not produce the required speed for one hull, but that we do not produce the same speed for two, three, or more hulls of the same form and tonnage. Neither do we understand exactly all we should, about the form of the screw and the number of the blades best applicable for a certain hull; indeed, so far is this certain that within the last few years anecdotes of a curious and amusing turn have been related on this subject; one is, that lately a screw steamer, homeward bound, knocked off one of the blades of her screw; on putting into the nearest port for repair, it was discovered that there was no means for repair within too great a distance for the purpose. The ship's carpenter's abilities were called into aid by the captain as a last resource, in the shape of making a wooden blade of duplicate form with the original; but as it had to fit into the seat of the metal one, it could not be larger at the root, and was therefore of lesser strength throughout. This fact, of course, was sufficient to condemn the affair in the minds of the engineers of the ship, who knew something of the strains capable of being resisted by materials; "for if the metal was of the right proportion for strength, of what use could the wood be?" said they. It happened, however, that the ship was propelled with the compound blades at the rate of a knot and a half per hour more than before, with the same number of revolutions. Another mysterious fact is related that, in several instances, by the loss of a blade or a portion of either, a greater speed for the hull has resulted after than before the accident.

In all our late scientific discussions on screw-propulsion it has been acknowledged by several authorities that there is more to be learnt, more to be accomplished, and therefore more energy to be applied in the solution of the problem before us. To attain this we must not forget, in any instance, "what has been done;" we must be posted up in the latest and best examples, and, as the best means of assistance, those examples are herein introduced for the benefit of the profession. What they consist of in the main are three classes—the "common," "Griffiths'," and the "Mangin." The common screw derives its name from the fact that it is the most simple to construct, being, indeed, but a portion of the helix of a complete screw, or, in principle, as the examples geometrically considered in Plates 2 and 5. It has another feature, also, which must not be overlooked, *i.e.*, the blade is of the same pitch throughout its length, or from the root to the tip; and that the plan, side, and end views in their natural form are sharp-cornered at the widest extremities. The present practice is to alter the natural outline of the blade by curving back the leading edge considerably, and slightly rounding off the trailing corner.

The number of blades used with the common screw was only two for some time, but within the last three or four years screws of this class have had three, four, and six blades, but only in one or two instances have five blades been adopted.

The lineal section of the blades has been straight as a rule, at right angles with the longitudinal centre line of the boss; but in some cases the sections have leaned forward and backward from the boss, according to the taste and opinion of the designer.

L

Next the Griffiths' screw was introduced, and is now largely adopted, principally in the navy. The peculiarity in this propeller is that its form is a direct contradiction of that of the common screw, while the final result of the duty of both are nearly equal. The Griffiths' screw has a large boss; the form of the blade is widest about the midway of its length, decreasing slightly at the boss, and narrowest at the tip, or top edge. The lineal section of the blade is curved towards the bow, the curve being commonly termed the "lean-to forward." This propeller has only two blades generally, but in some instances three, while occasionally four blades have been adopted.

The geometry of this propeller has often been held up as something mysterious. We have, however, explained and illustrated the matter fully from page 49 to page 69, so that the student can understand it clearly. We may add, that in the work on "Modern Marine Engineering" an illustration of it first appeared.

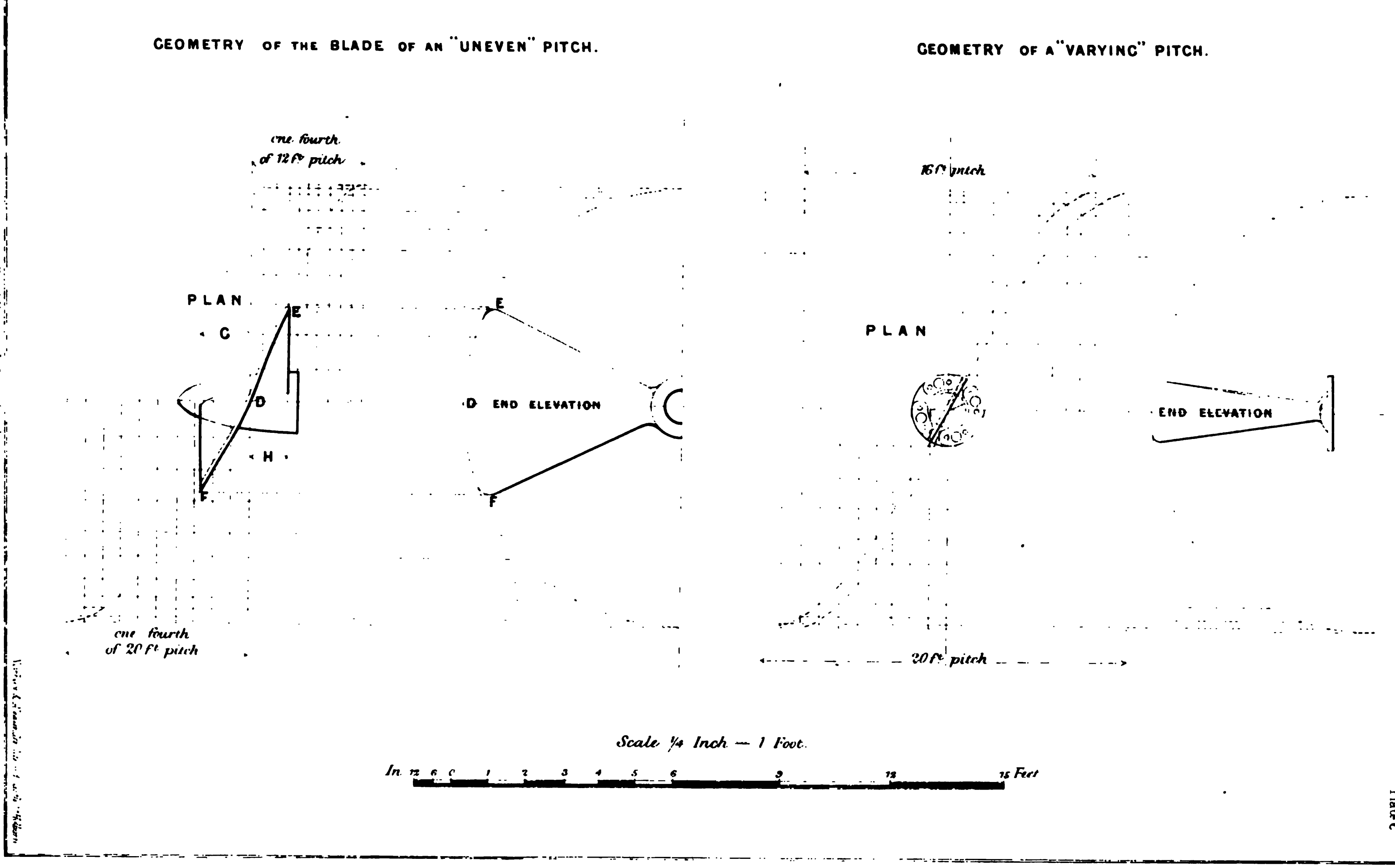
The Mangin example now has to be explained; this propeller has been geometrically treated in Plate 6; in page 36 the explanation has been given. The main feature in it is that by an uneven pitch a certain advantage in the matter of propulsion is attained; and, indeed, so far is this deemed possible by the inventor, that he has introduced two double-bladed screws with uneven pitches in advance of each other on the same boss. This position for two screws, however, is not due to him entirely, for it had been used for the common screw also for some time previously.

We now direct attention to the illustrations and particulars of the most modern examples of screw-propellers, by the most eminent makers in England and Scotland. The drawings are prepared with care from the working drawings which have been lent by the constructors for the purpose; they are, therefore, of equal value as the originals, and become at once of use as a guide to the engineer and instructive to the student.

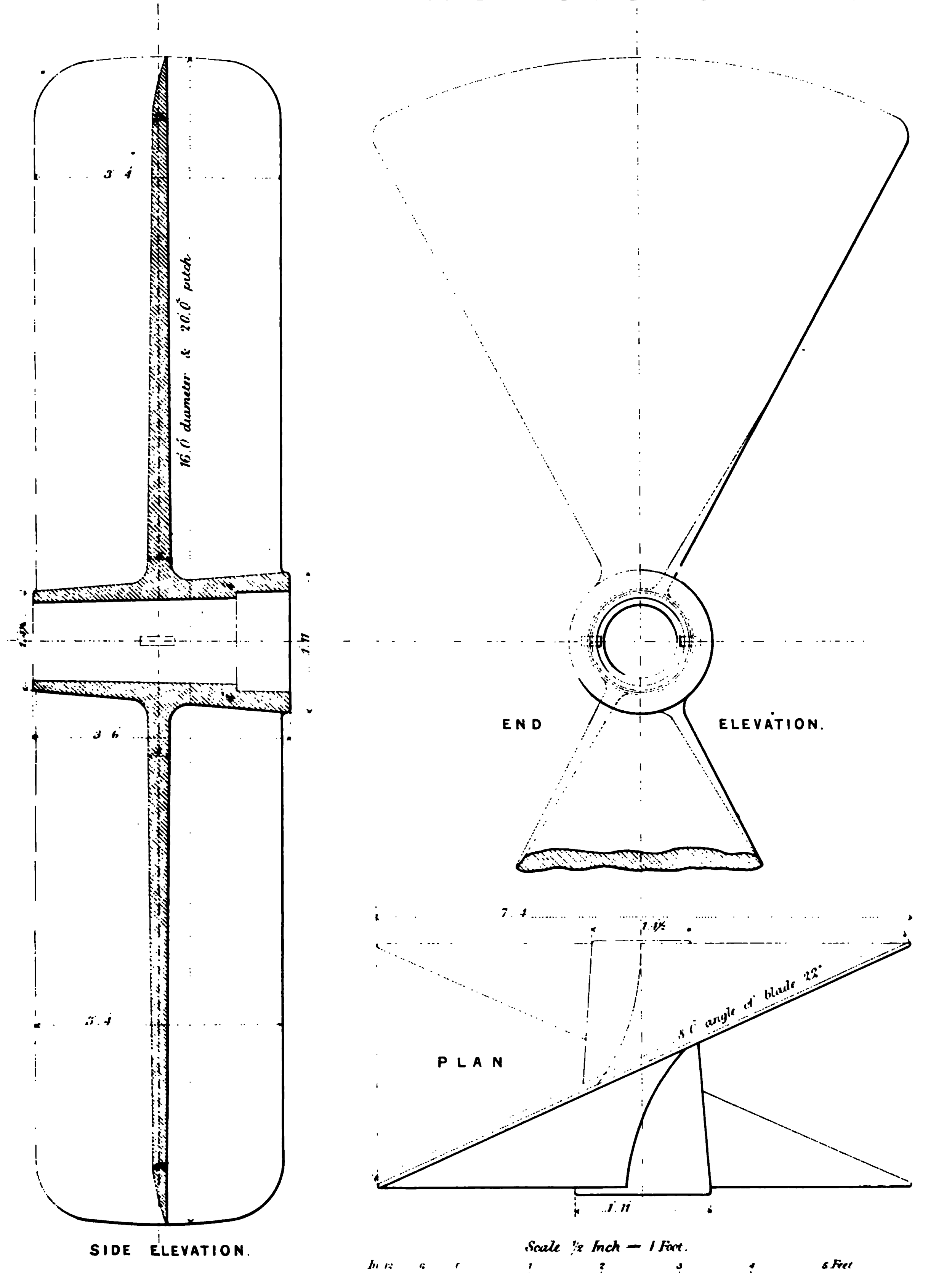
COMMON SCREW-PROPELLER, BY MESSRS. JAMES WATT AND CO.—PLATE 8.—This example is practically illustrated in three views: the side elevation shows the boss in section, also the blades; which explains, too, the relative thickness of each portion; the end elevation is projected from the plan below it, and corresponds also with the first view. The class of this propeller is termed, not only "common," but "duplicate" also, in relation particularly to the form of the blade, which is equidistant on each side of the centre line in all the views. The diameter of the boss in relation to that of the screw is somewhat smaller than generally adopted, but illustrates the minimum amount of metal that is requisite for sufficient strength around the shaft. The boss is secured on the shaft by a lateral key passing through both.

This type of propeller has been used to "overhang" from the forward bearing, as well as being supported fore and aft with a lifting frame. An example of the latter arrangement was fitted by Messrs. Watt to Her Majesty's troop-ship *Simoon*, and as the lifting frame is of a novel character we will explain it. The peculiarity lies in the

GEOMETRY OF THE SCREW PROPELLER.

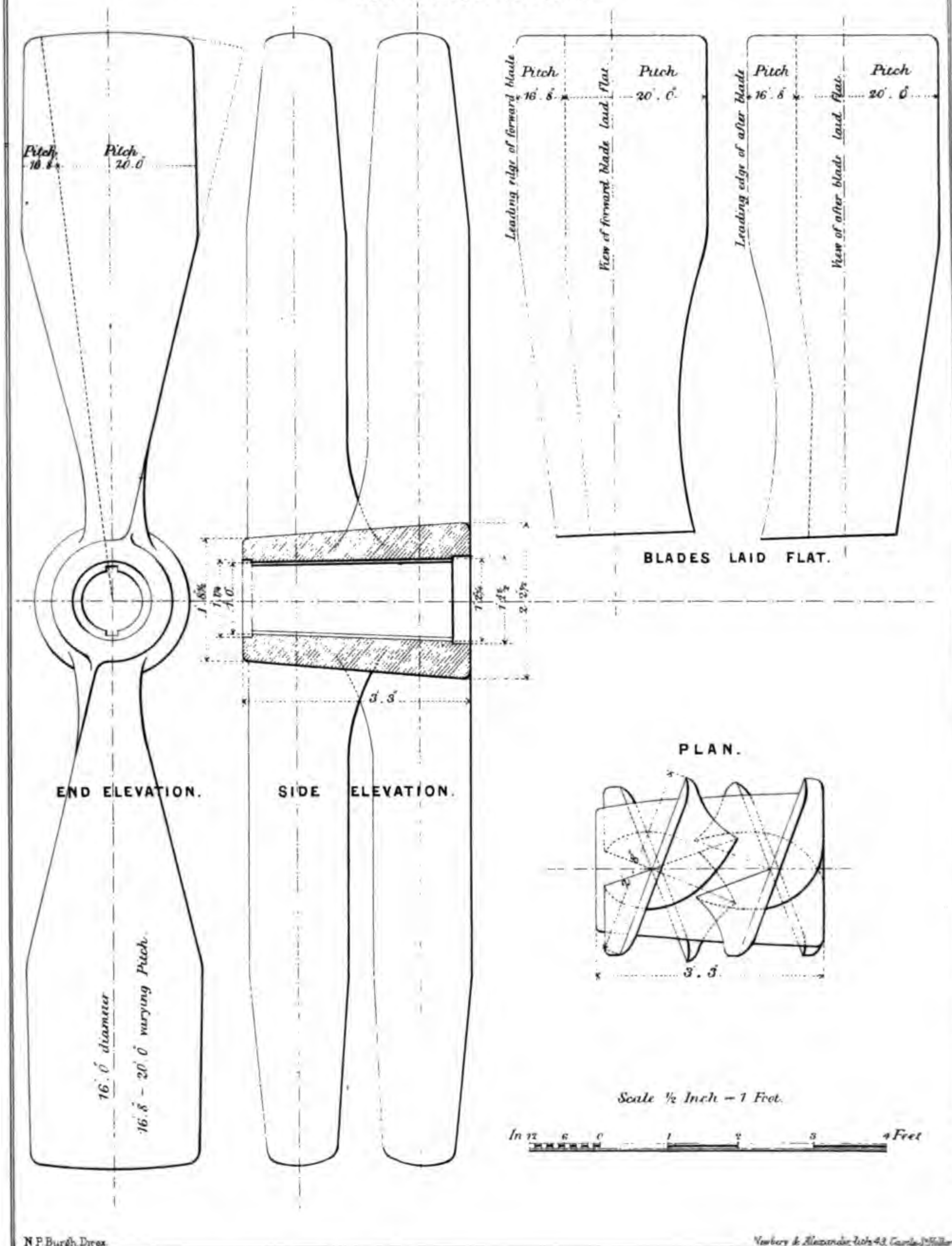


COMMON SCREW PROPELLER. BY MESSRS JAMES WATT & Co



F Burgh Direx

"MANGIN SCREW" CONSTRUCTED BY MESSRS HUMPHREYS & TENNANT. FOR H.M.S. "FAVORITE."



N. P. Burgh, Direx.

Newbery & Alexander, Lith. 43, Castle St. Holborn.

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mechanical means for raising and lowering the frame and propeller, being that the fore and aft vertical sides of the frame have teeth on the back ribs. These teeth are $1\frac{1}{2}$ in. pitch, and commence at a point 1 ft. 3 in. from the centre of the bearing of the shaft, extending therefrom to a height of 8 ft. The cross frame joining the side frames is situated at a distance of 8 ft. 10 in. from the centre of the shaft. On each side of the vertical frames are worms or short screws 7 in. diameter, the threads being pitched to gear with the teeth on the frames. The shafts of the screws are supported in suitable bearings secured to the hull, they are $3\frac{1}{2}$ in. in diameter and 12 ft. 8 in. long, extending to the deck of the ship.

At a height of 7 ft. 2 in. from the worms in gear with the frame teeth are similar worms keyed on the shafts, their use being to gear with the frame when it reaches those points on rising, and also acting as guides at the same time. The vertical distance between the centres of these worms or screws is 7 ft. 11 in., and the lift of the propeller is 11 ft. 7 in. It is obvious that the mechanical operation is, that by turning the worms around suitably in either direction the frame is raised and lowered.

"MANGIN SCREW," CONSTRUCTED BY MESSRS. HUMPHREYS AND TENNANT. PLATE 9.—The main features in this propeller are that the blades are of an uneven pitch and are situated in advance of each other. The end elevation of the blades forms a striking contrast with the side view: as in the former view, the blade is narrower at the boss than beyond, but in the latter this form is reversed. The flattened shape of the blade shows that it is parallel from the top for a certain depth, and from that point is straight at an angle on one side and curved inwards opposite. The plan shows the four blades as they would appear when situated either vertical or horizontal. The boss is secured on the shaft by two longitudinal keys; the shaft being slightly conical and the boss formed to correspond. The connexion of the two pitches on the blade is at one-fourth of the full width, starting from the leading edge. The length of the blade on the line of keel at the various points of change of shape are thus: at the top the length is 12 in., at the parallel width it is 17 in., and at the connexion with the boss it is 21 in., which gives a mean width of 16·66 in.

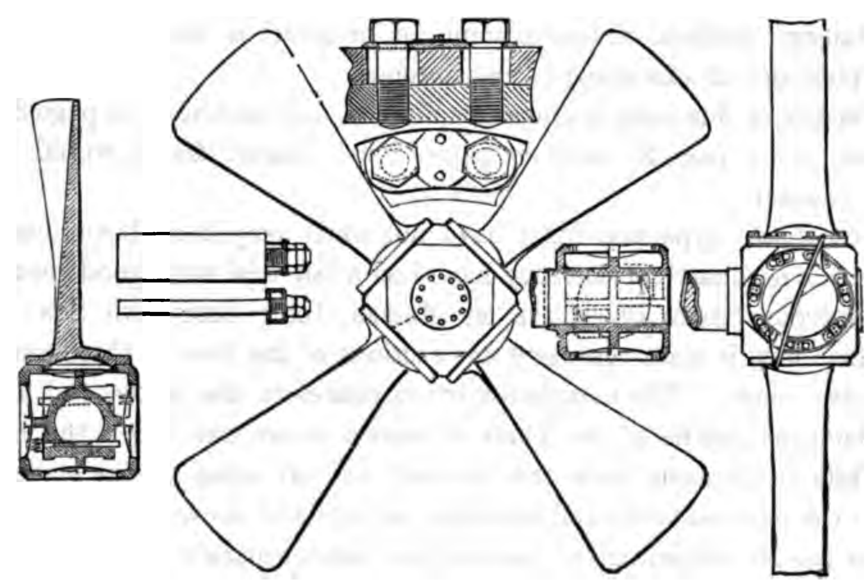
Besides H.M.S. *Favourite*, this class of propeller has been fitted by different makers to other ships; for instance, the *Bullfinch*, has this type of propeller fitted to her, alluded to by Mr. Rennie in page 17 of this work, and illustrated there by the accompanying plate.

On February 20th, 1868, Her Majesty's corvette *Blanche* was put through her official trial of speed, being fitted with a "Mangin" screw-propeller: the diameter is 14 ft. 7 in.; the pitch of the leading portion of the blade is 15 ft. 7 in., and that of the following portion 17 ft.; the mean length of the blade on the line of keel being 12 in. These proportions gave a result of speed of 13·631 knots per hour for the ship, the screw

making 88·5 revolutions per minute with full boiler power; while with half boiler power a speed of 11·78 knots per hour was attained.

The official report also states that the action of the "Mangin" screw driven with full power was accompanied by the heavy thumping action upon the stern of the ship, immediately over the screw at each revolution, that was so marked a feature in the vibratory action attending the working of this screw in the experimental trials made with it in competition with other screws in the trials made some five or six years since with the *Shannon* frigate.

Another type of Mangin screw of recent introduction is illustrated by Fig. 22.

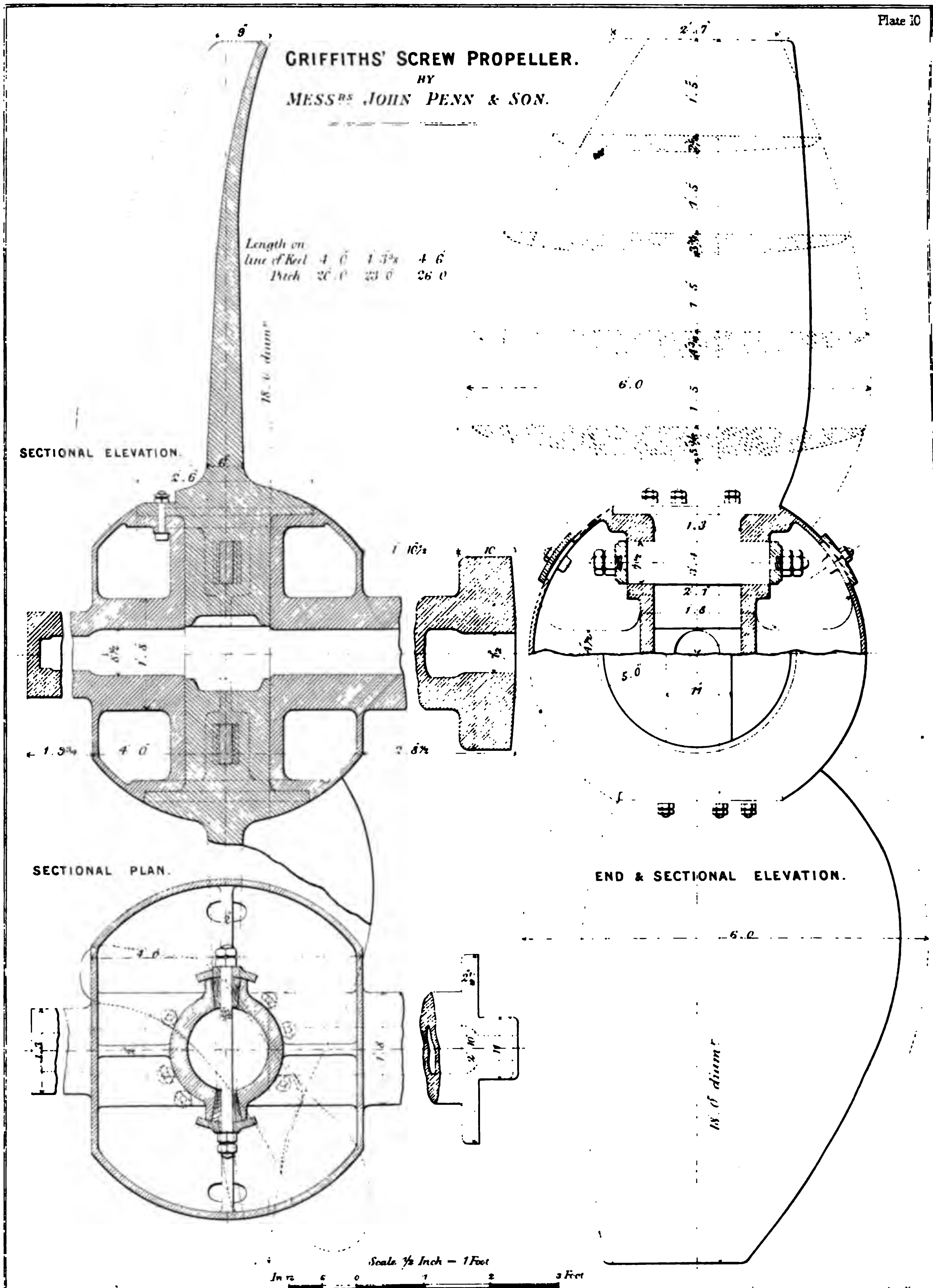


Sectional Elevation. End Elevation. Side Elevation.

Modern 4-Bladed "Mangin" Screw-propeller.

Fig. 22.

This propeller has four blades directly opposite each other, and secured to the boss by studs only; the advantage from this connexion being of a twofold character; that in the event of a fracture of a blade when cast with the boss, the entire propeller has to be replaced; but if the blade were secured to the boss a new blade only is required. The other portion of the advantage is that when the blade is a fixture on the boss, the pitch is unalterable, but when it is separate, it can be adjusted at any angle and thus secured to the boss. The connexion of the blade in this case is a flange, with a fitting rib inside; the stud-holes are oval—as shown by the large section above the boss between the two upper blades. The studs are the ordinary kind with hexagonal heads, and are prevented from looseness—when screwed up—by stop plates as shown in the view, the plates being secured by studs of a lesser diameter. The boss, it will be noticed, is


GRIFFITHS' SCREW PROPELLER.
BY
MESSRS JOHN PENN & SON.
Length on line of Keel 4 0 1 3¾ 4 6
Pitch 26 0 23 0 26 0
18. 0 diamr
SECTIONAL ELEVATION.
SECTIONAL PLAN.
END & SECTIONAL ELEVATION.
6. 0
18. 0 diamr
Scale ½ Inch = 1 Foot

square with the corners cut off beyond the flanges—this is shown distinctly in the end and side elevations. The sectional plan of the boss is between these two views, the blades being omitted. The sectional elevation is a transverse section of the boss and a vertical section of one blade: in this view the connexion of the blade is seen, and as each are duplicates only one is depicted. Between this view and the end elevation is a plan and side view of one of the keys and nuts for securing the boss on the shaft. The application of these keys is shown in the sections; it being that the boss is secured by the keys passing through projections in the boss, and lateral channels cut in the shaft opposite each other; the nuts prevent the keys from slipping, and when the blades are connected the whole affair is hidden as shown by the complete views.

The "Mangin" portion of this example of propeller is shown in the end elevation; which is the plan also of one blade of two pitches.

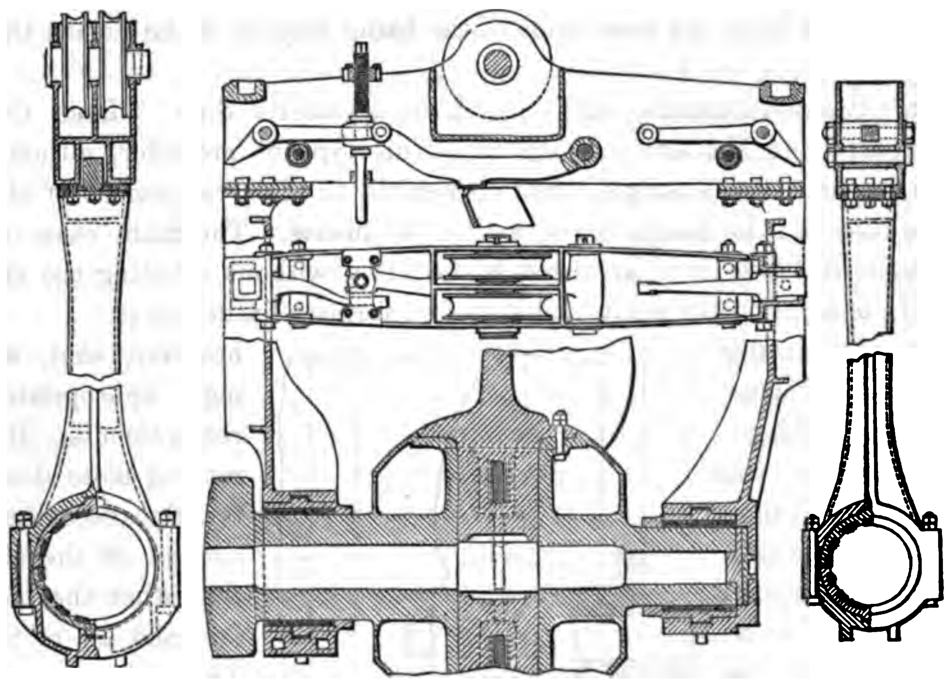
The geometry of this form is shown in Plate 6, and described in page 36; the present illustration also is on page 37, and on page 38 it is stated that it would be again introduced in this chapter.

Propellers of this type and form have not until very lately been introduced in the navy, but for the merchant service they have had a fair trial with good results.

THE GRIFFITHS' SCREW-PROPELLER BY MESSRS. JOHN PENN AND SON. PLATE 10.— The illustrations in this plate represent the sections of the boss in three views and that of the blades in two views. The complete portion relates to the blades and half of the boss only. The flattened outline of the blade is shown above and below the boss in the end elevation; while in the side view the forward and aft sides of the blades are seen; in this view also the vertical section of the blade is depicted showing the amount of lean-to. This propeller has the advantage of having the blades separate from the boss, so that, as we stated before, in the event of a fracture or requiring adjustment, the blade can be replaced or suitably secured. The method adopted for securing the blade is two-fold in its mechanical contrivance, being by a key, also bolts and nuts. The keys are secured at each end by double nuts; spaces in the boss are formed not only to receive the keys but also the stop or adjusting wedges; these wedges are prevented from slipping out by cross pieces or caps through which the round portions of the key passes. This will be fully understood by noticing the sectional plan, also the side views of the detail, which is shown in the sectional portion of the end elevation.

The plan of the blade is represented in dotted lines, showing thereby the position of the blade when set at the mean or constructing pitch, therefore the thickness of the wedges is equal throughout. Now, if it were required to adjust the blade suitably for a greater or lesser pitch, these wedges now in place would have to be replaced by others of unequal but appropriate thickness and thinness, and when all were fixed the key would be askew, instead of central, as illustrated.

The next feature to be noticed in this example of propeller is that it is suspended in bearings fore and aft, the gudgeons being cast or formed with the boss with a "cheese" coupling at the forward end; this is known as the "lifting" type, and the frame is often termed the "banjo" frame, because the end views of the fore-and-aft bearings resemble that instrument in outline. As the frame is not shown in the plate, we illustrate an example of it and the propeller in position by Fig. 23.



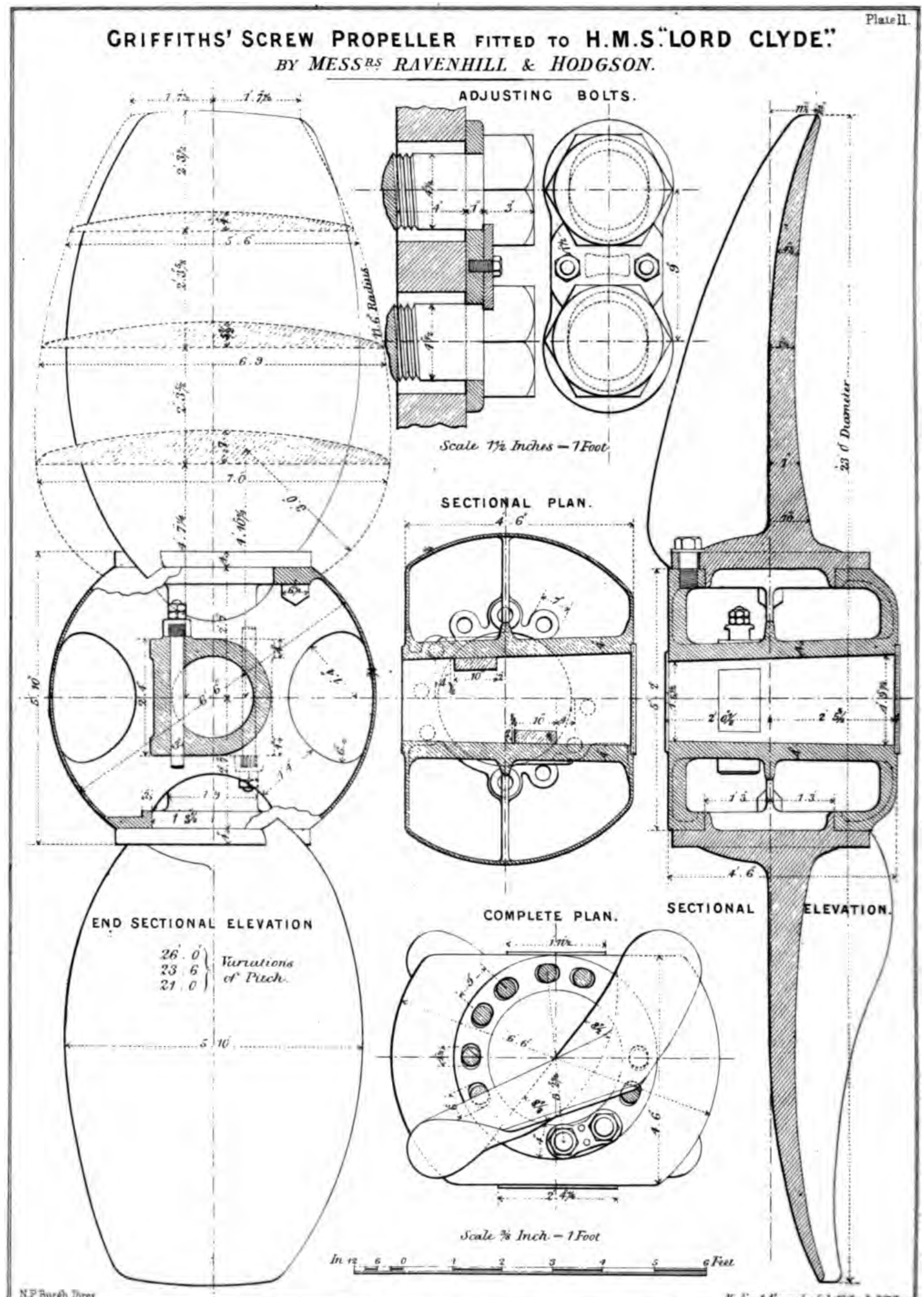
Forward Side Frame. Sectional Elevation and Plan. Aft Side Frame.

Griffiths' Screw-Propeller and Lifting Frame by Messrs. Penn.

Fig. 23.

The sectional elevation shows the propeller boss and the gudgeons; the bearings also with the lignum-vitæ strips; the transverse sections of these bearings and their end views can be understood from the other views of the fore and aft frames. The bearings proper and the suspending portions are connected by bolts and nuts, and the two guide lugs projecting below to fit into the stern and rudder-post brackets respectively.

Directly over the propeller and the bearings is the complete plan of the cross-piece connecting the frames, showing also the fittings within it; above this the sectional elevation of the framing is completed, with the other views of the fittings. The rope-pulleys are shown in both cases, also in the sectional portion of the forward side frame.



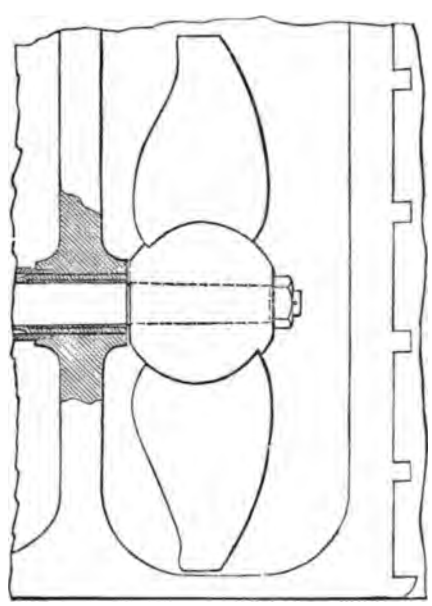
E. & F. N. Spon 48 Charing Cross, London

The mode of raising and lowering the stop-lever for the blade is by a screwed rod having collars, between which the double end of the lever is fitted; this is seen in plan, elevation, and section. The ratchet-catches at each end are also shown in plan and elevation, the forward catch being bent to make room for the central position of the rod of the stop-lever.

The sides of the frame are connected to the cross-piece by bolts and nuts, instead of being in one casting, as is the practice by some other makers. The recessed portion at each end of the cross-piece is for the lower ends of the fixing stays to fit into when the frame is lowered.

GRIFFITHS' SCREW-PROPELLER, FITTED TO HER MAJESTY'S SHIP "LORD CLYDE," BY MESSRS. RAVENHILL AND HODGSON.—PLATE 11.—This type of propeller, although of the same class as the preceding example, differs materially in the arrangement of the internal portion of the boss and the flange connexion for the blades. The main cause for this is that the propeller in Plate 10 is arranged to be lifted without affecting the shaft, while this in Plate 11 is *keyed* on the shaft, and therefore forms a fixture on it.

Propellers of this order are now becoming universal, while the "lifting" kind are getting in the background. This change of opinion and practice have not met with the difficulties which were once said to be certain, which are, in the main, that when the propeller overhung the bearing of the shaft, the weight of the former would affect the true position of the latter; and as that weight, in some cases, is from 15 to 20 tons, there seemed to be some foundation for the doubt. It has been lately proved, however, that, with bearings appropriate to the requirements, this heavy moving mass does not materially affect the working contact of the shaft more than when the bearings are fore and aft of the screw. The modern practice in relation to the matter of position can be fully understood from the illustration Fig. 24, which depicts the propeller, stern and rudder posts, also a section of the bearing for the shaft.



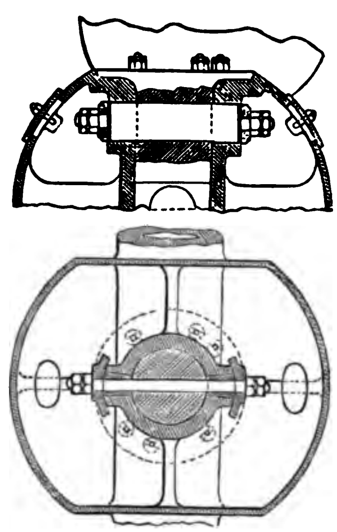
Elevation of the Modern Mode for Supporting the Screw-propeller.

Fig. 24.

The illustrations in Plate 11 represent a complete working drawing of the propeller under notice and the details. In the end elevation the flattened outline of the blade and the cross sections are shown, and also the complete views when the blades are set at the constructing, or mean pitch. Corresponding with this are the vertical sections, and the complete portions beyond. The connexion of the blades with the

boss is by studs only, being the same modern mode as that shown by Fig. 22, in page 76.

We may remark that this simple means for holding or securing the blade in the position required, as a certainty, was for some time doubted; it being thought that the studs could not sufficiently connect the flange to the seat on the boss, therefore, the key and wedges were the universal additional means adopted for some time.



Sectional Plan and Elevation of the Key and Wedges for adjusting and securing the Blade of the Griffiths' Screw-propeller.

Fig. 25.

As a contrast to the connexion shown in the plate, we illustrate the key and wedge method by Fig. 25, which shows at once the addition alluded to, also represented in Plate 10.

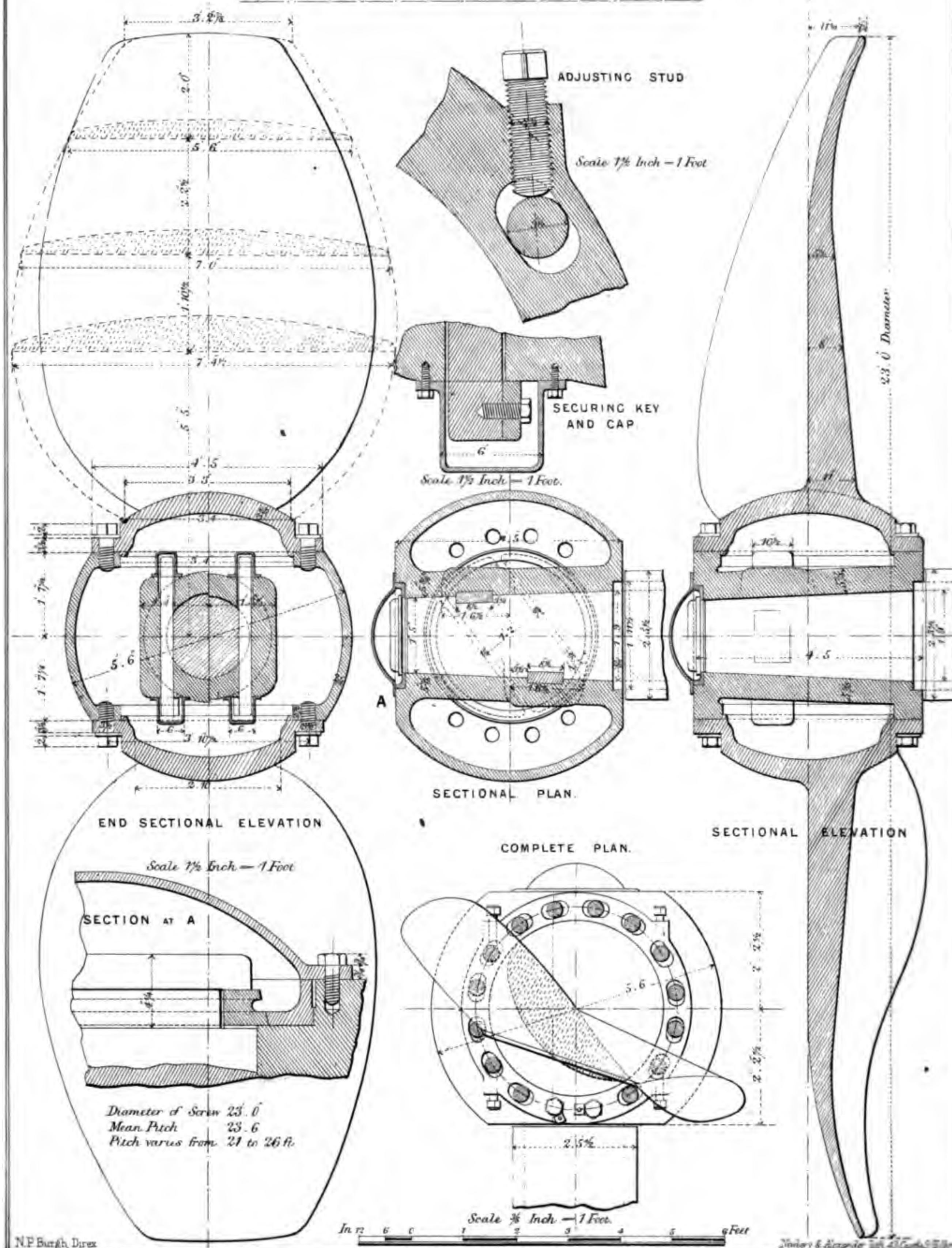
It is not always the practice to arrange the key and wedges at right angles to the line of keel, for in some cases an angle of 45° has been adopted with solid ribs at right angles throughout on the inside of the boss.

Referring again to the Plate, it is noticed in the sectional elevation that the length of the boss is within the limit of the following side of the blade, but level with the outline of the leading side, the flange also is set back from the forward end of the boss. There is one advantage with this arrangement, and it is that the boss is shortened to its minimum length, and thus the weight and material are reduced to the lowest quantities. The sectional plan of the boss shows the form of the outline between the flanges, which is equal portions of a sphere on each side of the centre line; the thickness of the metal around the shaft is the same in both views, and the respective positions of the keys are also apparent. The side view of one key and cross-section of the boss at that point is shown in the end elevation, also the dotted outline of that opposite. The detail of the adjusting studs and the method of preventing their becoming loose are shown at a larger scale, between the two upper blades they are precisely as those for Fig. 22, in page 76; examples of which have been constructed by the same firm. The number of the studs in each flange are shown in the complete plan, also their position in relation to the angle and section of the root of the blade. The radius of the pitch circle of the studs is 1 ft. $7\frac{3}{4}$ in.; the flange holes are sufficiently elongated to allow the blade to be shifted from its present position—which is at the constructing or mean pitch—$\frac{11}{16}$ of an inch for the maximum pitch, and $\frac{3}{4}$ of an inch for the minimum, on the pitch circle; but at the edge of the flange the preceding fractions are altered to $\frac{23}{32}$ of an inch, and $\frac{13}{16}$ of an inch respectively.

The plan of the top blade is shown and as much of the lower blade as can be seen beyond the boss. The form of the blade when laid flat—shown in dotted lines in the end elevation—is the same for both edges; which agrees with the geometry illustrated by Plates 7 and 7A, the complete elevation of the blades are also similar.

GRIFFITH'S SCREW PROPELLER FOR H.M.S. "LORD WARDEN."

CONSTRUCTED BY MESSRS. MAUDSLAY SONS & FIELD.



N.P. Burgh, Direx.

Newbery & Alexander Lith.

E & F N Spon, 48, Charing Cross, London.

GRIFFITHS' SCREW-PROPELLER FOR HER MAJESTY'S SHIP "LORD WARDEN," BY MESSRS. MAUDSLAY, SONS, AND FIELD. PLATE 12.—The diameter and pitches of this propeller and the one illustrated in Plate 11 are the same, the cause for the similarity being that the *Lord Warden* and *Lord Clyde* are sister ships in the royal navy. The illustrations under notice represent three views of the boss in section, one being a transverse view, the second a plan, and the third longitudinally or on the line of the keel.

The end sectional elevation—which shows the transverse section of the boss—depicts the complete views of the blades, also the flattened outline and the cross sections, as in Plate 11. The sectional elevation represents the boss and blades in section—this being the longitudinal section of the boss—so that the lean-to of the blades is seen, and the shape of the leading and following edges. The sectional plan relates to the boss in the main, but it shows also the position of the securing keys.

The complete plan, as in Plate 11, illustrates the outline of the blades and boss, the number of securing studs for each flange, and the stop or set plates in position for two studs.

As these two propellers belong to two sister ships in all particulars, which are also of national importance as to their speed, we will compare, first, the leading features in the mechanical arrangement of the boss portions of the two screws, with the difference in the proportions, and next the results of the latest trials.

The diameter of the shaft in the boss of the *Lord Clyde* screw is 1 ft. $9\frac{7}{8}$ in. at the forward end, and 1 ft. $6\frac{1}{2}$ in. at the aft end, while the shaft in the boss of the *Lord Warden* screw is 1 ft. 9 in. and 1 ft. 5 in. respectively. The thickness of the boss around the shaft for the *Lord Clyde* is 4 in., but that for the *Lord Warden* is $5\frac{5}{8}$ in. The length of the taper in the former is 4 ft. 6 in., and in the latter 3 ft. $11\frac{1}{2}$ in. The length of the boss of the *Lord Clyde* screw is 4 ft. 6 in., but in the *Lord Warden* screw it is 4 ft. 5 in.; the diameter of the first is 6 ft. 6 in., and of the second 5 ft. 6 in. The front face of the boss is 2 ft. $5\frac{1}{2}$ in. from the centre of the flange of the blade in the *Lord Clyde* screw, and the back face is 2 ft. $\frac{1}{2}$ in., while for the *Lord Warden* it is 2 ft. $2\frac{1}{2}$ in. on each side of the centre of the flange.

The securing keys for the former screw are each 10 in. wide and 3 in. thick, secured from shifting by nuts and a raised washer—a similar key, washer, and nuts, are shown in detail in Plate 20; but the securing keys of the screw for the *Lord Warden* are $8\frac{1}{2}$ in. wide and $3\frac{1}{8}$ thick, the slipping being prevented by a side piece secured to the top of each key by two studs—this is shown in detail above the sectional plan of the boss. The extremities of these keys are capped, it will be noticed, to keep the sea water from them and thus prevent corrosion in their seats. The length of the holes for the keys in the first example is 2 ft. 4 in., and 2 ft. $4\frac{3}{4}$ in. in the second.

The faces for the flanges of the blades in the *Lord Clyde* screw are 2 ft. 7 in. from

the centre of the boss on each side; but in the *Lord Warden* screw they are 1 ft. 7¼ in. only from the centre.

The diameters of the two different flanges of the blades are 3 ft. 11½ in. and 4 ft. 5 in. respectively; the diameters of the securing or adjusting studs are 4½ in. for the one and 3½ in. for the other. The main cause for this vast difference in the diameters being that in the *Lord Clyde* screw there are only ten of these studs; four on the front side of the blade and six at the back; whereas for the *Lord Warden* screw there are *sixteen* adjusting studs equidistantly pitched; the diameter of the pitch circle of the former is 3 ft. 3½ in. and the latter 3 ft. 10½ in.

Then as to the comparative areas of the studs, 4½ diameter = 15·9 area, and 15·9 × 10 = 159 square in. for the total area; next 3½ diameter = 9·621 area, and 9·621 × 16 = 153·936 square in., so that the total area of the adjusting studs for each blade of the *Lord Clyde* screw is only 5·064 square in. more than that for the *Lord Warden*.

The thicknesses of the two shells of the bosses are much more varied than might be supposed from the previous proportions, in the first example the shell is only ¾ in. thick at the globular part, and 1¼ in. at the flats or ends, with one rib 2 in. thick, connecting the shell to the boss; in the second example, the globular portion is 2¼ in. thick, with no rib of any kind, the thickness at the ends being 3⅜ in. The strengths, therefore, of the two bosses are about equal, although there is so much difference in the form and relative proportions.

We now compare the blades—the *Lord Clyde* screw-blade is 10 in. thick at the root, 5½ in. where the lean-to commences, and $\frac{11}{16}$ in. at the tip; for the *Lord Warden* at the same points the blade is 11¼, 5½, and 1¼ in. thick.

The width of the blade of the former is 4 ft. 5 in. at the boss, 7 ft. maximum, 6 ft. 9 at the commencement of the lean-to, and 3 ft. 3 in. at the tip; for the *Lord Warden* the dimensions of the blade at these points are 3 ft. 3 in., 7 ft. 4½ in., 7 ft., and 3 ft. 2⅜ in. wide, the amount of lean-to being 11½ and 11¼ in. respectively; and the flanges of the latter are ribbed inside with two ribs 1½ in. thick and 1 ft. 2 in. apart.

The modes for securing the adjusting studs in the two examples are widely different; for the *Lord Clyde* it is by a flange or stop-plate with studs, but for the *Lord Warden* it is set plates and studs, two of which are shown in the complete plan, also in detail in Plate 19.

It will be noticed that the shaft of the *Lord Warden's* screw is fitted with a thrust-ring recessed in the boss; this ring is in halves and hooped in the groove formed for the purpose. A cap secured to the boss covers this arrangement, and also prevents any water entering. To make this fully understood, a portion of it is shown in section at a large scale below the boss in the end sectional elevation.

Having described the comparison of the arrangement and proportions of the two screw-propellers, we will now proceed with the results of the trials of the two ships.

The *Lord Clyde* and *Lord Warden* are wooden-built armour-plated ships, each 280 ft. long, breadth 58 ft. 11 in., and tonnage 4067. They are covered with armour plating of various thicknesses; thus, at the water-line above and below, for a certain distance, the plating is 5½ in. thick. At the ports, which are 8 ft. 9 in. above the water-line, for 3 ft. up and down the armour is 6 in. thick, in two thicknesses, one of 1½ in., bolted directly to the frame timbers of the ship, and the remainder 4½ in., secured as usual on the outside of the planking. The armour is continued to a depth of 6 ft. below the water-line at midships, and on each side of this, or fore and aft, it terminates at 4 ft. 6 in. below the same level. We now describe the trials.

TRIAL OF THE "LORD CLYDE."

Draught of water forward	23 feet.
" " aft	27 feet.

Full boiler power.	Number of revolutions of the screw per minute.	Speed of the ship in knots per hour.
1st run	64	13·846
2nd "	64	12·721
3rd "	65	14·285
4th "	65	12·413
5th "	63	14·694
6th "	65	12·040

Mean speed of ship in knots per hour	13·666
Mean number of revolutions of the screw per minute	64·33
Mean total number per hour	3859·98
Mean speed of the ship with half boiler power in knots per hour.	11·736

FULL BOILER POWER CIRCLES.

Number of revolutions on entering	64
" " after entering	60

HALF BOILER POWER CIRCLES.

Number of revolutions on entering	50
" " after entering	47
Diameter of screw-propeller	23 feet 0 inches.
Pitch—set	23 feet 6 inches.
Number of Blades	2

TRIAL OF THE "LORD WARDEN."

Draught of water forward	23 feet 7¼ inches.
" " aft	27 feet 8¼ inches.

Full boiler power.	Number of revolutions of the screw per minute.	Speed of the ship in knots per hour.
1st run	63	13·636
2nd "	63·8	13·235
3rd "	63·3	14·062
4th "	63·5	12·95
5th "	63·3	13·74
6th "	63	13·33

Mean speed of the ship in knots per hour	13·492
Mean number of the revolutions of the screw per minute	63·31
Mean total number per hour	3798·6
Mean speed of the ship with half boiler power in knots per hour	11·777
Mean number of the revolutions of the screw per minute	52·52
Diameter of screw-propeller	23 feet 0 inches.
Pitch set	21 feet $4\frac{1}{2}$ inches.
Pitches adjustable	22 feet 6 inches to 27 feet 6 inches.
Number of blades	4

This propeller, it will be noticed, is not the same as that illustrated in Plate 12; but examples of the class are shown by Plates 19 and 20; the latter is similar to the original screw fitted to the *Lord Clyde,* which is four-bladed with uneven pitches and adjusting blades secured by studs, also illustrated by Fig. 22 in page 76.

The two-bladed screw will be fitted, in due time, to the *Lord Warden,* when a better comparison of the results of the two screws illustrated will be more apparent than at present, as only that fitted to the *Lord Clyde* can be said to have been fairly tested.

CHAPTER VIII.

ON TWIN SCREW PROPULSION.

By Messrs. J. and W. Dudgeon.

NOTHING has added so much to the importance and value of the steam engine since its practical introduction by Watt, as the various improvements made from time to time in its applicability to the propulsion of ships, and those who are conversant with the history of the steam engine will recognise the host of contrivances proposed, and modes employed by various inventors for this purpose. The two great divisions of these plans come under the systems of paddles and screws. Paddle wheels with their latest improvements, including the feathering float, have maintained their position, and are still employed by steam-ship owners, in a large proportion of the high-class ocean ships, so that although the screw is an economical substitute, and in many cases a great improvement on the paddle system, and has received considerable modification from time to time as experience has shown to be necessary, it has not until recently been employed to propel ships at really high velocities. Further, so far as the single screw is concerned, it is not entirely applicable to vessels of light draught, and is also not fully efficient for manœuvring purposes.

Now, as light draught, high velocity, and facility for manœuvring are qualities of importance for vessels, either for war or commerce, any modification of the system of propulsion which can in any degree secure those good qualities must be an improvement, and if while thoroughly securing those advantages, it possesses many others, it must in many, perhaps eventually in the majority of cases, supersede other systems.

Our experience of the independent twin or double-screw system has abundantly proved to us that it surpasses any other system of propulsion yet introduced, so far, at any rate, as the above-named qualities are concerned, and as we have taken a somewhat prominent part in practically introducing and working it out, we will briefly describe how we arrived at our experience of it.

In the year 1861 we were consulted as to the construction of a screw vessel of about 120 horse power for the navigation of very difficult shallow waters, and of a large power in proportion to tonnage, to fit her for towing purposes. Another requirement was, that the vessel should be especially handy for manœuvring. Under these circumstances it appeared to us advisable upon mature consideration, to adopt twin screws, working independently, and each driven by a pair of engines, although, so far as we were aware, no attempt had been made to fit any sea-going vessel in that manner; the experiments which had been made with connected twin screws having been attended with but little success. We however felt convinced that if carefully carried out the principle was sound; we therefore advised its adoption, and early in 1862 received the order to proceed with the vessel. On trial she more than answered our expectations, her extreme handiness in manœuvring, her speed, good sea-going qualities, and immunity from total disablement stamped her at once as the most suitable type for a blockade runner—that trade having sprung up while she was in course of construction—her owners seeing this, immediately put her upon that dangerous service; she continued in it with great success until bought by the Southern Confederacy. Her satisfactory performance at once brought us orders for seven vessels of about the same size, with engines from the same patterns, all of which on trial gave the same results, as their predecessor and sister ship the *Flora*.

The English Admiralty having from the first taken considerable interest in the performance of these vessels, as being likely to affect the question of the propelling power applied to ships of war, one of the earlier built ones, before being delivered over to the owners, was placed by us at the disposal of the Admiralty authorities, for experimental purposes. A series of experiments made with the vessel on behalf of the Admiralty under the direction of T. Lloyd, Esq., and the late J. Dinnen, Esq., gave satisfactory results. We received orders from the Admiralty for a small experimental vessel, and within little more than two years from the completion of our first independent twin-screw vessel, we had built twenty, from 400 to 1600 tons builders' measurement.

Advantages.—As there is still great diversity of opinion as to the advantages of twin screws, it will be well to state the principal elements of their superiority. They are, in our view, the following:

1st. Greatly increased facility for handling and manœuvring the ship.

2nd. The avoidance of risk of detention from accidents and adjustment of the machinery for both screws at the same time.

3rd. The advantageous application of large power in the case of high-powered vessels, especially when they are of light draught.

4th. Safety and steadiness in the event of the ship being hove to.

5th. Greater freedom of the propellers from disturbing currents and broken water arising from the motion of the ship, the sternposts, dead wood, and counter.

6th. The reduction of weight by nearly half in each of the moving parts.

The first of the advantages claimed—viz., that of increased facility for handling and manœuvring the ship, especially in close quarters—is one of great importance in all vessels, pre-eminently so in those for war purposes.

In the case of a single-screw vessel—leaving out of the question the action of the sails—she can only be turned by means of the rudder, which ceases to act when the vessel has no motion through the water; whereas twin screws, working independently, will, by simply reversing their action, cause the vessel to revolve in a circle whose diameter shall very little exceed her own length; and, in case of the rudder being carried away, the ship can be steered with perfect ease by regulating the relative speed of the propellers and the direction of their revolutions, as circumstances may require.

This facility for manœuvring is of immense advantage to all vessels, whether intended for purposes of war or commerce. Narrow channels, which would otherwise be impracticable, can be threaded with perfect ease; the vessel can be turned round in a narrow river without running the risk of grounding either forward or aft during the operation, and the difficulties of navigation are in many ways greatly reduced; while, for war purposes, the advantages of a twin-screw vessel can hardly be over estimated. She has the option of position with regard to an enemy, having the power of placing herself either end or broadside on with rapidity and certainty; and, though she may only be fitted with a fixed battery instead of a revolving turret, she can, with her turning power, act as a turn-table to the battery without risk arising from derangement of the turning gear; it becoming possible, in this way, to dispense altogether with the whole of that complicated and expensive machinery, for even in the unlikely event of one propeller becoming disabled, she is still a manageable seaworthy vessel if her rudder is not carried away.

This naturally brings us to the second point of advantage, viz., that of the avoidance of the risk of detention, from accidents and adjustment of the machinery. This, especially in the case of long ocean voyages, is of great importance; inasmuch that in the case of a single-screw vessel, a break-down generally disables her to a serious extent, but the twin-screw vessel can be kept on her course with no great diminution of speed for hours or even days together; adjustment of parts can be effected with ease, or even the break-down of one pair of engines may occur, and no serious inconvenience arise, seeing that while the one propeller is disconnected, and its engines are being overhauled, the other is driving the vessel about ·8 of her full speed, if the lines are tolerably fine, as then the angle is very small which the rudder makes with the keel to keep the vessel on a straight course; and although, in short bluff vessels, this angle of rudder and the consequent absorption of

power by it are greater, such vessels have, on the other hand, the advantage over those of finer lines in turning capabilities, the fulness of the fore and aft bodies offering less resistance; and the distance between the centres of the screws being greater in proportion to the length of the vessel, gives greater power to overcome that resistance.

The third point—the advantageous application of large power in the case of high-powered vessels, especially when they are of light draught—is equally important, as the diameter of the propeller is generally very closely limited by the draught, frequently to such an extent as to make it very difficult to make a single propeller of sufficient diameter economically to absorb the power exerted by the engines; this difficulty is at once obviated by twin screws, as they can each be made as large as the single one. Although, as a general rule, there is a considerable margin as to the draught of seagoing steamers, yet the smaller diameter for the propellers, where two are used, is still advantageous, inasmuch as the centres—and consequently the upper edge—of the propellers will be at a greater distance below the surface of the water, which will give a better resistance for the propellers to work against, setting less water in motion, and giving more economical results.

By whatever distance the centres of the smaller pair of propellers below the surface of the water exceeds that of the large single one, the difference of immersion of the upper edges will be at least twice as great, so that the range of difference of immersion of the stem of the ship in a seaway will have to be much greater than with a large propeller before it affects its regular action. This is felt to be a great advantage, both when running and going head to wind; for, although marine governors are excellent things in their way, their action is only an approximation to what is wanted, as they are frequently found, in bad weather, to be quite inadequate to cope with the action of the sea and engines on a large propeller, the upper edge of the blade being perhaps not more than a foot below the load water line. Any arrangement of the screws by which the tendency of the engines to race is lessened, must therefore be beneficial, both as regards economy of fuel and the safety of the machinery.

The greatest benefit, however, from the smaller propellers is obtained when the vessel is running, as then the racing is worst, and is productive of worse effects.

As long as the vessel is going head to sea, the bad consequences of racing can be greatly diminished by lessening the average speed of the engines; but with a heavy sea aft, any reduction in the speed of the engines, and consequent retarding of the ship, is very apt to cause water to come on board over the taffrail, which, in vessels with no spar decks and plenty of light deck houses and skylights, is a most serious matter. The racing is worst when running, because the propeller is longer out of the water at each time in proportion to the relative speeds of the waves and the ship; as, for instance, suppose the speed of the vessel to be 10 knots, and the speed of the sea or waves 18 knots, then, when

running, the waves would pass the vessel at 8 knots, but head to sea at 28 knots; and it follows that the engines would have 3½ times as long to increase and decrease their speed during the passage of each wave, as they would have going head to wind. The option, therefore, of using smaller propellers in greater depths of water, secured by the twin-screw arrangement, is clearly an advantage in the case of ocean steamers.

In the case of light-draught vessels requiring large power in proportion to the tonnage, the twin-screw arrangement presents peculiar advantages; in fact, it makes it possible to double the propelling power, in the case of a screw vessel, while it also greatly increases her handiness. It is therefore useful for light-draught gun-boats, and all vessels required for service on shallow, intricate waters, where, as in many cases, the paddle-wheel is unsuitable or entirely inapplicable.

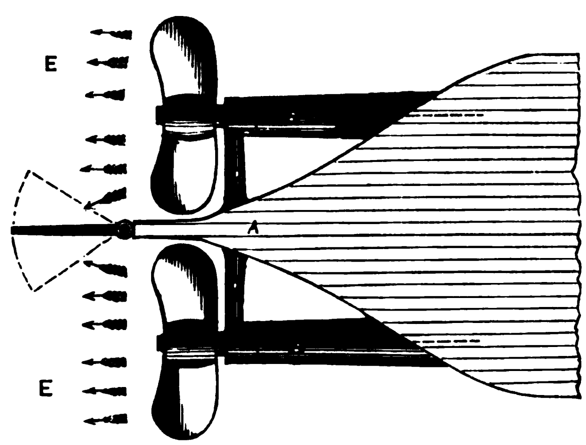
The greater safety and steadiness, in the event of the ship being hove to, which we have mentioned as the fourth point of advantage, is also of no mean importance; for example.

When a vessel is hove to, the great desideratum is to keep her as near as possible at the same angle with the sea, so as to subject the hull to the minimum of strain, and to prevent her shipping water. In such a case, in consequence of the vessel making but little headway, the action of the rudder is very doubtful; also in the case of a steamer it therefore devolves on the sails and machinery to keep her steady, and as, in the majority of full-powered steamers, the sails are very small and often badly placed, this duty, after all, comes from the machinery. With a single screw, the only way in which the direction of the ship's head can be regulated is by increasing the speed of the engines, so as to give greater steerage way; this increased speed being very objectionable on account of straining the vessel by driving her head to sea. On the other hand, with twin screws, the centre of action of the propelling power can easily be transferred to the weather or lee quarter, according as the vessel tends to come up or fall off, by regulating the relative speeds of the propellers, or by stopping one entirely.

The next advantage named is; the greater freedom of the propellers from disturbing currents and broken water arising from the motion of the ship, the sternposts, dead wood, and counter. In all single-screw vessels, where the propeller revolves in an aperture in the dead wood, there is necessarily more or less of loss of propelling power arising from the checks which the propeller blades receive in passing the sternposts; the water in the first place being disturbed and broken by the after-body of the ship before it arrives at the propeller, especially where the lines of the vessel are full; and then, when projected aft by the blades of the propeller in what should be nearly a solid unbroken column, it is caught between the after sternposts and the passing screw blades, and again broken up; and in this way much of the power which should go towards the propulsion of the vessel is worse than uselessly expended in giving a series of shocks to the stern frame, causing vibration with all its serious evil effects.

These evils are almost entirely obviated by the use of twin screws, as, in the first place, they are much less liable to be affected by the currents caused by the passage of the vessel through the water, being situated at such a distance from the hull as to be almost unaffected by its action upon the water; the column of water driven aft by the blades being also free to move onwards, and the propeller to revolve, without obstruction of any kind.

The diagram, Fig. 26, will serve to illustrate this subject, and to some extent shows the arrangement which we have found to be most satisfactory in practice. A is the after part of the hull of the vessel. B B, the stern tubes, each consisting of a plated shell forming part of the ship, and constructed in such a way as to allow of its being damaged or filled with water without causing a leak into the ship. These shells enclose ordinary stern tubes, similar to those used in single screw vessels, and are carried at the after end by the A brackets, D D. These brackets are forged of an oval form, so as to offer as little resistance to the water as possible, and are strongly secured to the ship and connected to each other by a transverse bulkhead.



Action of Currents with Twin Screws.

Fig. 26.

It will at once be seen that by this arrangement, the propellers are almost beyond the influence of the currents caused by the ship's motion, while the columns of water E E, put in motion by them in the process of propulsion, are free to pass directly aft without the slightest obstruction.

The reduction by nearly half of the weight of each of the moving parts, in consequence of the distribution of the power, though of little or no consequence in the case of small powers, becomes a very great advantage where large engines are concerned. The untrustworthiness of very heavy forgings, such as crank shafts, &c., and the damage to machinery accruing from the heavy shocks of ponderous masses of metal in rapid motion, and constantly changing the direction of that motion, are too well known to require further mention here. They are, however, among the greatest difficulties which have to be met in the employment of high powers, and can in no way be so satisfactorily obviated, as by the adoption of independent twin screws.

Having thus stated our views as to the leading advantages of the twin-screw system of propulsion, we will now cite one or two examples of the actual performances of different classes of vessels in illustration of the subject.

As a suitable example as to how far this especial system meets the requirements of a fast merchant steamer, employed in an ordinary passenger and carrying trade, we may instance the twin-screw steamer *Mary*, plying regularly with passengers, cattle, and general cargo between London and Gothenburg.

The following are a few particulars of the dimensions of the vessel and machinery.

Length between perpendiculars	230 feet.
Breadth	27 „
Depth to spar deck	20 „ 2 in.

Tonnage, B. M. 829 tons.

She is propelled by two three-bladed propellers, one right and one left handed, working outwards, and quite independent of each other, and each driven by a pair of horizontal direct-acting condensing engines, with cylinders 37 in. diameter, 21 in. stroke, ordinary injection condensers, with double-acting air pumps, driven direct from the ends of the piston-rods, which are continued through stuffing boxes in the covers of the cylinders for that purpose; double port slide-valves worked by link motion. Boilers, 2 in number, having 6 furnaces in each, 3 at each end, with separate combustion chambers towards the middle of boiler, and a water space between. Tubes of iron having a total surface of 4290 square feet, the total fire-bar surface being 210 square feet. There are two funnels with annular superheaters at their bases.

She was completed, and tried at the measured mile, on the Maplin Sands, in August, 1865, averaging on trial a speed of 14·12 knots, and was immediately afterwards placed upon her station in the North Sea trade. In this, which is unquestionably one of the most trying services to ship and machinery which could well be found, she speedily established her superiority over all competitors, making the passage from London to Gothenburg, over 650 miles, in an average of 48 hours, a speed never before approached by any regular North Sea trader. She very soon became, through her speed and sea-worthy qualities, the favourite ship, both for passengers and cattle, bringing over heavy freights and large numbers of animals in perfect safety; also was the only one which was ever again heard of out of five steamers which passed the Scaw for England on the 29th of December, 1866, the rest having foundered with all hands, while she, with a full cargo, made her passage in safety through a terrific gale, arriving 10 hours after her time, with the loss of but one bullock only.

On one occasion she presented one of the most severe, but perfectly conclusive, tests possible, as to the trustworthiness of the peculiar stern tube arrangements, and the great serviceableness of the twin-screw system generally.

About twelve months since, when bound to London, during foggy weather, with a considerable sea on, and while turning one screw ahead and the other astern to escape stranding on a sandbank, the starboard propeller struck the bank, and was, with the

shaft, entirely carried away. Now, had the vessel been either paddle or single screw, she might perhaps under the circumstances have been lost, but the steam being immediately shut off from the starboard engines, she came up to London at the rate of 10 knots per hour with the port engines, retaining her steering powers sufficiently for the sharpest bends of the river; it being found sufficient to keep the rudder over 5° only, to make a straight course. When the vessel was docked, the stern tubes, frames, &c., were examined, and found to be quite uninjured by the severe shock which they had sustained.

This vessel having served as a sufficiently conclusive example of the applicability of the twin-screw system to trading vessels generally, the weatherly qualities it confers, and its safety in the case of bad weather or accident, the Panama, New Zealand, and Australian Royal Mail steamer *Ruahine* may be further taken as an illustration of its applicability to ocean steamers.

When, with a view to reducing the distance by about 2000 miles between England and New Zealand, the direct mail route viâ Panama was decided on, there were two paramount considerations that had to be entertained in building vessels for the Pacific portion of the line.

The first was that, by the terms of the contract entered into between the company and the Government, an average speed of 10 knots per hour had to be maintained from port to port.

The second, and most difficult consideration, as the distance between the ports is 6670 knots—by far the longest direct steaming voyage in the world with no halfway coaling station—was the selection of an efficient form of vessel, with very large fuel carrying capacity, and machinery possessing the three requisites of the greatest possible efficiency, safety and economical working, and so constructed as to reduce the probabilities of loss of time by break-down, to a minimum.

After careful consideration of various designs, the directors gave orders to four different firms in England and Scotland, each to build a steamer expressly for this service, and the one entrusted to us for construction was the twin-screw *Ruahine*, of 1600 tons and 350 horse power.

The arrangement of the propelling machinery is very similar to that in the *Mary* before described, except that, to attain economy of fuel, she has expansive engines with high and low pressure cylinders one within the other, and Davison's surface condensers, she also has annular superheaters with diaphragms. Both engines and boilers are completely illustrated in the work, "Modern Marine Engineering," by Mr. Burgh. The coal bunkers have a capacity of 1200 tons, to enable her to carry the requisite quantity of fuel for so long a voyage.

She was completed in May, 1865, tried at the Maplin Sands, realising a mean speed of 13 knots, and afterwards made a trial cruise down channel for further experiments,

especially as to her consumption of fuel upon long distances. The fuel being carefully weighed by the representatives of the company, was ascertained to be at the rate of 2·6 lb. per actual horse power per hour.

As the other vessels of the fleet were not ready, it was decided still more thoroughly to test her capabilities by actual service at sea; she was therefore chartered to the Royal Mail Company, and was employed for six months on the intercolonial station between St. Thomas's and Colon. In this service she gave the authorities great satisfaction, and at the conclusion of the charter, returned to England to refit, and sailed for Sydney, where she arrived in June, 1866. Since that time she has been making her trips between Sydney, Wellington, and Panama, with great regularity; having run about 130,000 miles without derangement or injury of any kind to the propellers, or any other part of the twin-screw arrangement.

One of her recent voyages to Panama, ranks among the quickest passages ever known, the vessel having run from Sydney to Wellington (1250 knots), and from Wellington to Panama (6670 knots) without stoppage, in all 7920 nautical miles, in 31½ days.

As the best criterion of the practical work done by the twin-screw system is to take the particulars of performance during an actual voyage, we append an abstract of the engineer's log of the *Ruahine* on double voyage from Sydney to Panama; the real results being there clearly shown.

ABSTRACT FROM LOG OF STEAMSHIP "RUAHINE" ON HER SIXTH VOYAGE FROM SYDNEY TO WELLINGTON, COMMENCING MARCH 1ST., AND ENDING MARCH 6TH, 1868.

Date.	Lat.	Long.	Distance run.	Steam.	Revls.	Vacuum.		Coals.		Slip per cent.	REMARKS.
						Fore.	Aft.	Per 24 hours.	Quality.		
Mar.	° ′	° ′	Knots.								
1			25	22	72	25	24	9 0			6.30 A.M., lit fires. 9.10 A.M., full steam. 9.40 A.M., passed P. & O. steamship *Bombay*. 9.55 A.M., Sydney Heads.
2	35 29	156 44	257	18	64	25½	26	35 10	Colonial, good.	6·6	Smooth water; fair wind; all sail set.
3	37 15	161 14	238	20	67·2	25½	26	37 0		18	No wind; fine weather; boilers priming.
4	38 26	165 49	232	21	69	25	26½	38 5		22	Fore-and-aft canvas set; P.M., ship pitching heavily.
5	39 44	170 24	228	22	69	24	25	40 0		23·7	Fore-and-aft canvas set; head wind and sea.
6	41 4	174 53	214	21½	66·4	24½		40 0		25·8	8 A.M., Steven's Island; 0.15 P.M., made fast to coal hulk in Wellington Harbour.
			42	22	68	24		7 0			

	Tons.	Cwt.
Coals on board, leaving Sydney	1015	11
,, Consumed to Wellington	206	15
Banked fires, galleys, &c.	3	5
Remains on arrival	805	11

Abstract from Log of Steamship "Ruahine," on her sixth Voyage from Wellington to Panama, commencing March 8, and ending April 4, 1868.

Date.	Lat.	Long.	Steam.	Distance run in 24 hours.	Revls.	Vacuum. Fore.	Vacuum. Aft.	Coals.	Quality.	Slip per cent.	Remarks.
Mar.		East.									March 8, 2.30 P.M., moved engine; 4.10 P.M., Wellington Heads. Head wind and sea.
	° ′	° ′									
9	41 55	179 10	20 18	192	66·6	25	25½	23 0	Welsh.	2·0	5 A.M., set square sails. 8 P.M., stopped starboard engine to screw up coupling bolts.
		West.									
10	41 46	174 55	19	263	65	26	24	25 0		4·4	Strong fair wind, all sail set; P.M., wind very light.
11	42 2	169 23	19	246	63·6	26	25	26 0		10·5	Strong fair wind, all sail set. Condensing with distilling apparatus.
12	42 13	163 34	19	259	64·4	26	25	29 0		7	Moderate breeze, and fair wind; all sail set. Condensing.
13	42 16	158 21	20	232	65·3	26	24½	32 0	Mixed.	18	Light winds, with occasional calms.
14	42 24	152 48	20	247	68	26	24	32 0		15	Strong winds and fair; all sails set. Condensing.
15	42 24	146 45	20	269	67·2	26	24½	30 0		7	Fresh breeze and fair. Swept tubes with steam up.
16	42 15	140 38	19½	273	66·3	26	24	29 0	Welsh.	4	Fresh breeze and fair; all sails set. Condensing.
17	41 31	135 21	19	241	67·3	25	24	27 0		16	Fresh breeze and fair; all sails set. Light winds.
18	40 32	130 19	20½	235	67·8	24		33 0		19	8 A.M., stopped after engines, to screw up connecting rods and repair counter; 8.15 A.M., started.
19	39 35	124 49	19	267	66·2	24½		32 0		8	Increasing breeze; now fresh gale, with rain.
20	37 44	120	18	236	63·3	24		30 0		14	Weather moderating; ship rolling heavily; light winds.
21	35 44	115 23	21	254	69·5	25		34 0		15	Light winds and fair weather. Condensing.
22	33 20	111 12	20	254	69	24		33 0		15	Light winds, squally with rain. All square sails set.
23	30 47	107 11	20	255	70	24		33 0		16	Steady breeze and fine. All sails set.
24	28 15	103 17	20	253	70·2	24½		34 0		16·5	Light variable winds and smooth sea. Swept tubes with steam.
25	25 49	99 49	21	235	69·3	24		34 0		21	Light head winds. Fore and aft canvas set.
26	22 30	97 18	21	242	69·4	24½—24½		33 0	Colonial.	18	11.43 A.M., shut stop valves, and packed 4 cylinder glands, adjusted eccentric straps, connecting rods, and started at 0.40 P.M.
27	18 57	95 20	21	240	69·1	24½—25		34 0		18	Moderate breeze. Fore and aft canvas.
28	14 49	94 3	21	259	71·2	24		33 0		16	Light variable winds. Square sails set.
29	10 53	92 11	21	260	71·3	24		32 0		16	Light variable winds. Swept tubes with steam.
30	7 05	89 42	22	272	73·6	25		34 10		16	Moderate breeze and fair, and smooth water. All sails set.
31	3 28	87 26	21	256	70	24½		36 10		15	Wind very light and variable.

EXTRACT FROM LOG OF STEAMSHIP "RUAHINE" (*Continued*).

Date.	Lat.	Long.	Steam.	Distance run in 24 hours.	Revls.	Vacuum.		Coals.	Quality.	Slip per cent.	REMARKS.
						Fore.	Aft.				
Apr.	North.										
1	0 7	84 57	20	261	69	24½		34·0	Colonial.	13	Smooth water and calm.
2	3 13	82 10	21	250	71	24½		34·14		24	Light winds and variable. 8 A.M., head winds and sea.
3	6 29	80 40	21	202	68½	25		36·14		28	Strong head wind and sea. 6 P.M., passed Island of Malpelo.
4	Flemenco.		22	164	71	25—24		31·0		28·5	6 A.M., Tobago. 7 A.M., anchored at Flemenco.
								855·8			

Time occupied, 26 days 8 hours.

		Tons.	Tons.	Cwt.
Coals on board leaving Wellington . . .	Welsh .	230	1035	0
	Colonial	805		
Consumed in propelling ship			855	8
Galleys, winches, &c.			13	18
Remains			165	14

It must be remembered that this is no trial trip report, but the log of a voyage, made after the vessel had run for six months in the intercolonial mail service in the West Indies, made the voyage out and home, then made the voyage to the antipodes, and afterwards five double journeys across the Pacific, and a better nautical test to prove the suitableness of the arrangement for ocean navigation can scarcely be quoted.

For ease in handling the vessel where the channel is intricate, uncertain, or overcrowded—as on rivers—or when rapid manœuvring for fighting purposes—especially in close quarters—is required, the twin-screw system is particularly applicable; as will be readily seen by reference to the following results of manœuvring experiments.

EXAMPLE, No. 1.

The *Flora*, blockade runner, 425 tons, 120 horse power.

1st Experiment.—Full speed ahead with both engines, helm hard over, the circle was completed in three times the ship's length in 3 min. 33 sec.

2nd Experiment.—One engine going full speed, the other stopped, helm hard over on working side, the circle was completed in a little more than the ship's length in 3 min. 30 sec.

3rd Experiment.—One engine going ahead the other astern, helm hard over, the vessel turned completely round on the centre of her length in 3 min. 48 sec.

4th Experiment.—The engines going in opposite directions as before, but the helm fixed amidships, the circle was again made in the ship's own length in 4 min. 28 sec.

EXAMPLE, No. 2.

The *Edith*, afterwards *Chickamauga*, blockade runner, 531 tons, 200 horse power. Immersed midship section 180 square feet, displacement 510 tons.

1st Experiment.—Both engines going ahead, helm hard over, the full circle was made in 4 min. 3 sec.

2nd Experiment.—Screws going in opposite directions, the circle was performed in 3 min. 29 sec. The circle being completed, the engines were suddenly reversed, and their action on the vessel was instantaneous, the revolving motion of the ship being checked and reversed with the greatest ease. This experiment was repeated several times, and proved that a twin-screw vessel might in itself become the carriage for ordnance, which might be too heavy to be trained in the ordinary way.

3rd Experiment.—With one engine going, the other stopped, helm hard over, the full circle was completed in 4 min. 31 sec.

4th Experiment.—From order to put helm over, to time of putting ship in straight course at full speed in opposite direction, the circle was made in 1 min. 40 sec.

EXAMPLE, No. 3.

The *Handig Vlug*, gunboat, 138 tons, 40 horse power, for the Dutch navy, 100 ft. long and 17 ft. beam, heavily built, carries in her midship part a large rifle-proof citadel of steel plates. On her trial trip she accomplished ten knots per hour, being completely fitted out; with the exception of two twelve-pounders she was afterwards intended to carry.

1st Experiment.—The full circle was made by working the engines in opposite directions in 2 min. 53 sec.

2nd Experiment.—Going ahead full speed, the course of the vessel was reversed by the altered action of the screws in one minute, when she immediately ran at full speed in the opposite direction.

Two or three more examples in evidence of its applicability to vessels of high speed, will we think appropriately close our observations on the advantages of twin screws.

The *Atalanta* afterwards *Tallahassee*, blockade runner, 546 tons, 200 horse power nominal, 1220 indicated, midship section 160 square feet, displacement 510 tons, length 200 ft. Ran from Dover to Calais in 77 minutes, in a race with the Dover Railway Company's Steamer *Queen*, beating her by 30 minutes in that short run. She afterwards ran from Bermuda to Wilmington and back in 53 and 54 hours respectively = 1460 miles in 107 hours actual time steaming at sea = 13·6 per hour.

The *Mary Augusta*, blockade runner, 972 tons, 280 horse power nominal.

CHAPTER IX.

ON TWIN SCREW-PROPELLERS.

By N. P. Burgh.

THE results of the latest important trials of duplicate twin propellers fitted to sister ships form a suitable subject as an introduction to the present chapter; we therefore commence with the particulars of the trials of Her Majesty's twin-screw gun vessels *Viper* and *Vixen*, the engines for each being 160-horse power nominal collectively.

TRIAL OF THE "VIPER."

Tonnage	737 tons.
Length between perpendiculars	160 feet.
Draught of water forward	9 feet 11 inches.
" " aft	11 feet 10 "
Diameter of screw propellers	9 feet.
Pitch (variable from 10 ft. 9 in. to 13 ft. 3 in.) set at	9 feet 10 inches.
Length on line of keel	12 "
Immersion of upper edge	13½ "

Full boiler power.	Number of revolutions of the screw per minute, starboard.	Number of revolutions of the screw per minute, port.	Speed of the ships in knots per hour.
1st run	103·87	110·07	9·302
2nd "	109·10	114·75	9·756
3rd "	108·49	113·63	9·729
4th "	108·0	110·0	9·160
5th "	100·0	106·98	9·254
6th "	111·36	113·76	8·911

Mean speed of the ship in knots per hour	9·352
Mean number of revolutions of the starboard screw per minute	106·8
Mean do. do. port screw	111·53
Mean total number per hour starboard screw	6408
Mean do. do. port screw	6691·8

Half Boiler Power.

	Speed of ship in knots per hour.	
1st run	8·889	Mean speed 7·467
2nd do.	6·521	
3rd do.	7·877	
4th do.	6·581	

Mean number of starboard screw per minute	80·85
Mean do. port screw "	83·19

TRIAL OF THE "VIXEN."

Tonnage	754 tons.
Length between perpendiculars	160 feet.
Draught of water forward	9 feet 10 inches.
" aft	11 feet 11 "
Diameter of screw propellers	9 feet.
Pitch (variable from 10 ft. 9 in. to 13 ft. 3 in.) set at	9 feet 9 inches.
Length on line of keel	11¼ inches.
Immersion of upper edge	14½ "

Full boiler power.	Number of revolutions of the screw per minute, starboard.	Number of revolutions of the screw per minute, port.	Speed of the ships in knots per hour.
1st run	104·52	104·23	8·759
2nd "	107·13	106·98	8·780
3rd "	109·45	108·06	9·302
4th "	110·63	110·20	8·780
5th "	111·43	109·33	9·703
6th "	110·45	111·43	8·430

Mean speed of the ship in knots per hour	8·959
Mean number of revolutions of the starboard screw per minute	108·93
Mean do. do. port screw	108·37
Mean total number per hour, starboard screw	6535·8
Mean do. do. port screw	6502·2

Half Boiler Power.

	Speed of the ship in knots per hour	
1st run	9·625	Mean speed 7·443
2nd do.	5·660	
3rd do.	8·845	
4th do.	5·642	
Mean number of revolutions of starboard screw per minute	85·72	
Mean do. do. port screw	84·515	

Trial of Her Majesty's Gun Vessel, "Viper," when Manœuvring in Circles with full Boiler power.

No. of revolutions of Screws per minute before circling.	Angles of rudders at starting.	No. of revolutions of Screws per minute during circling.	Time of making the half circle.	Time of making the full circle.
To Starboard—both Screws working ahead.				
Starboard screw 109	Starboard rudder 28°	Starboard 106	1 min. 58 sec.	3 min. 20 sec.
Port screw 108	Port rudder 30°	Port 106	"	"
To Port—both Screws working ahead.				
Starboard 108	Starboard 30°	Starboard 106	1 min. 30 sec.	3 min. 5 sec.
Port 108	Port 30°	Port 106	"	"
To Starboard—Port Screw working ahead, Starboard Screw working astern.				
Starboard 110	Starboard 32°	Starboard 86	1 min. 32 sec.	3 min. 7 sec.
Port 101	Port 32°	Port 97	"	"
To Port—Starboard Screw working ahead, Port Screw working astern.				
Starboard 110	Starboard 27°	Starboard 108	1 min. 39 sec.	3 min. 9 sec.
Port 109	Port 27°	Port 94	"	"

TRIAL OF HER MAJESTY'S GUN VESSEL, "VIXEN," WHEN MANŒUVRING IN CIRCLES WITH FULL BOILER POWER.

No. of revolutions of Screws per minute before circling.	Angles of rudders at starting.	No. of revolutions of Screws per minute during circling.	Time of making the half circle.	Time of making the full circle.
To Starboard—both Screws working ahead.				
Starboard screw 109	Starboard rudder 37°	Starboard 112	1 min. 40 sec.	3 min. 20 sec.
Port screw 109	Port rudder 39°	Port 105	"	"
To Port—both Screws working ahead.				
Starboard 109	Starboard 27°	Starboard 102	1 min. 39 sec.	3 min. 9 sec.
Port 108	Port 27°	Port 94	"	"
To Starboard—Port Screw working ahead, Starboard Screw working astern.				
Starboard 110	Starboard 32°	Starboard 96	1 min. 3 sec.	3 min. 7 sec.
Port 111	Port 32°	Port 97	"	"
To Port—Starboard Screw working ahead, Port Screw working astern,				
Starboard 110	Starboard 32°	Starboard 108	1 min. 42 sec.	3 min. 9 sec.
Port 109	Port 34°	Port 94	"	"

TWIN-SCREW PROPELLER AND LIFTING FRAME FITTED TO HER MAJESTY'S GUN-VESSELS "VIPER" AND "VIXEN," BY MESSRS. MAUDSLAY, SONS, AND FIELD, PLATE 13.—The performances of this propeller having been expressed in detail, we now direct attention to its mechanical arrangement and form of the blades; knowing that these important points greatly regulate the results of the duty obtained. The plate for this purpose represents two elevations of one propeller and a plan; the lifting frame also being shown in section in each view. There is no peculiarity in the form or arrangement of the frame, as it is the ordinary type often used by the leading firms, and by the Messrs. Maudslay in particular. The cross piece is separate from the sides and secured by bolts and nuts; the forward propeller bearing is in halves in the usual way, and connected by bolts and nuts at the centre line—a plan of this portion is shown in the general plan—the aft bearing is formed of tubes with no means for adjustment.

As these propellers are the "lifting" class, the hulls are fitted with double stern posts for the purpose of sustaining the lifting frame fore and aft; their outlines are fully depicted in the side and end elevations, which also represent the connexions of the propeller bearings with them.

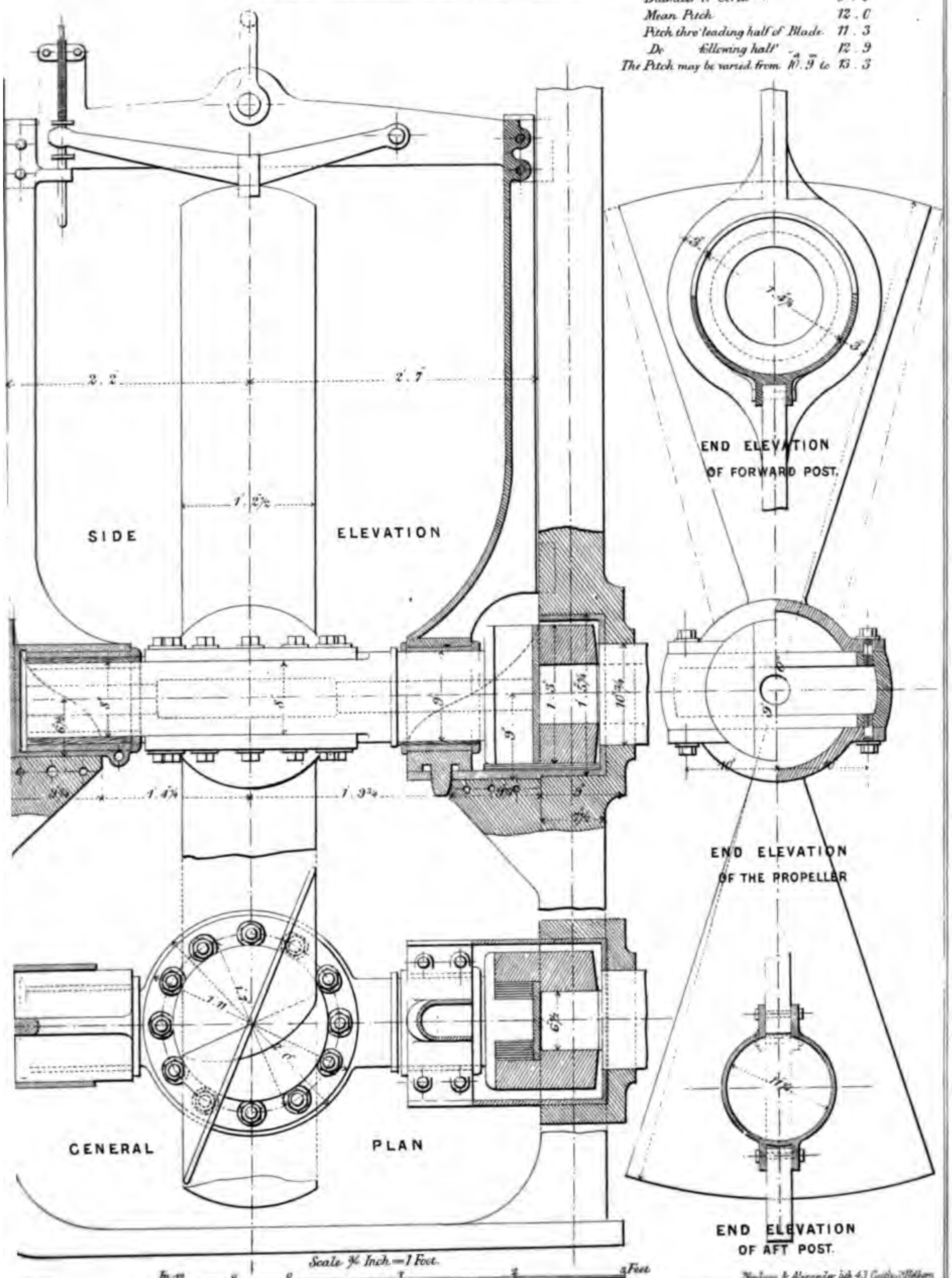
The novel feature in this matter is the arrangement of the propeller, or the connexion of the blades with the boss, and the form of the latter. The side and end elevations show that each blade is flanged to the boss, the latter being flat to correspond. Each flange is secured by bolts and nuts, and the holes are elongated sufficiently for the adjustment of the blade. The bolts are pitched equidistant—shown in the plan—and the nuts are retained in position by set plates.

The coupling for the propeller is the general "cheese" type; the grooved portion being secured on the shaft in the usual manner.

TWIN SCREW PROPELLER AND LIFTING FRAME FITTED TO H. M. GUN VESSELS "VIPER" AND "VIXEN"

BY MESSRS MAUDSLAY, SONS & FIELD.

	ft	in
Diameter of Screw	9	0
Mean Pitch	12	0
Pitch thro' leading half of Blade	11	3
Do following half	12	9
The Pitch may be varied from 10 ft. 9 in to	13	3



Dirse

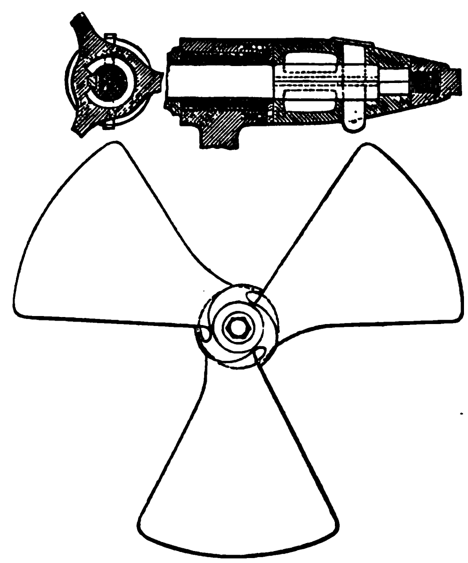
Newbury & Alexander lith. 43, Castle St Holborn

E. & F. N. Spon, 48, Charing Cross, London.

The form of the blade is a perfect radial segment of a circle, the geometrical outline is therefore complete, and the corners *not* "rounded off;" although this shape has given fair results it is often condemned by some authorities who insist that the corners must be curved; the leading corner having the larger radius.

The remaining feature in this example is the different pitches of the blade, which, as they are unequal on each side of the centre line, two distinct angles are formed from that point, similar as the "Mangin" propeller illustrated by Plate 19, and constructed by the same firm.

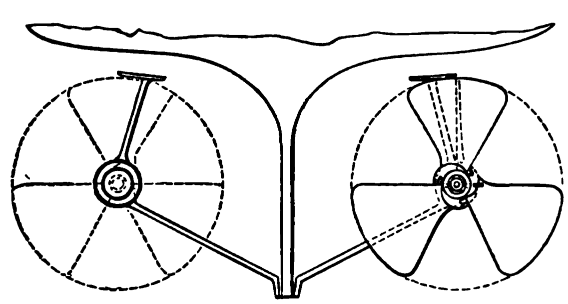
The type of propeller more universal than that previously described for twin screws, is the example illustrated above by Fig. 27; this has been recently fitted by Messrs. James Watt and Co. to the armour-plated steamships *Medusa* and *Triton*, the engines being of 200 horse-power nominal collectively for each vessel; one screw-propeller is right hand and the other left, both turning towards the hull. The diameter of each screw is 7 ft. 6 in., the pitch 11 ft., and the length on the line of keel 1 ft. 10 in.



Three-bladed Twin-Screw Propeller by Messrs. Watt.
Fig. 27.

The main mode of securing the propeller is by longitudinal and transverse keys as shown in the sectional views; a further means of securing being attained by the nut at the ends of the shaft and boss.

The shaft is supported in a tube of cast iron encased in a wrought-iron tube that is formed with the hull; the extremities of both the tubings being sustained by angular brackets as shown by Fig. 28.



Mode of supporting the Shaft-tubing for Twin-Screws with Brackets.
Fig. 28.

In this case the shaft is $7\frac{1}{2}$ in. in diameter, the bracket bearing being 11 in. and its length 15 in.; the arms are 8 in. wide and $2\frac{1}{2}$ in. thick, secured to the hull by rivets, the ends being flanged accordingly.

Twin Screw-Propellers, Stern and Shaft Tubing fitted to the Royal Mail Steamship "Ruahine," by Messrs. J. and W. Dudgeon, Plate 14.—The arrangement of tubing for supporting the shafts of twin screws is a matter on which the success of the system

greatly depends; so far indeed is this certain that there are several methods at present in practice for the same purpose. Amongst those most successfully carried out is that by Messrs. J. and W. Dudgeon, illustrated by Plate 14.

The sectional plan is a section of the hull through the centre line of the shafting. The shaft tubing is shown in section on one side and complete on the other. The sectional view depicts the stuffing box, gland, and bearing, the latter being formed of gun metal tubing and lignum-vitæ strips; beyond this is the outer bearing similarly constructed as the inner. The outer stern tubing or casing in connexion with the hull is of wrought iron plates; bent to a cylindrical form, and secured to the plating as shown. The supports are of wrought iron also, angular in arrangement—as seen in the sectional elevation—and secured at the most suitable points to the hull: the boss is shown in section, also the shaft bearing. On the opposide side, the section is taken through the forward end of the stern tube, so that the form of the plates to connect with the hull can be fully understood: the shape of the hull is amply shown not only in this view, but in the plan also.

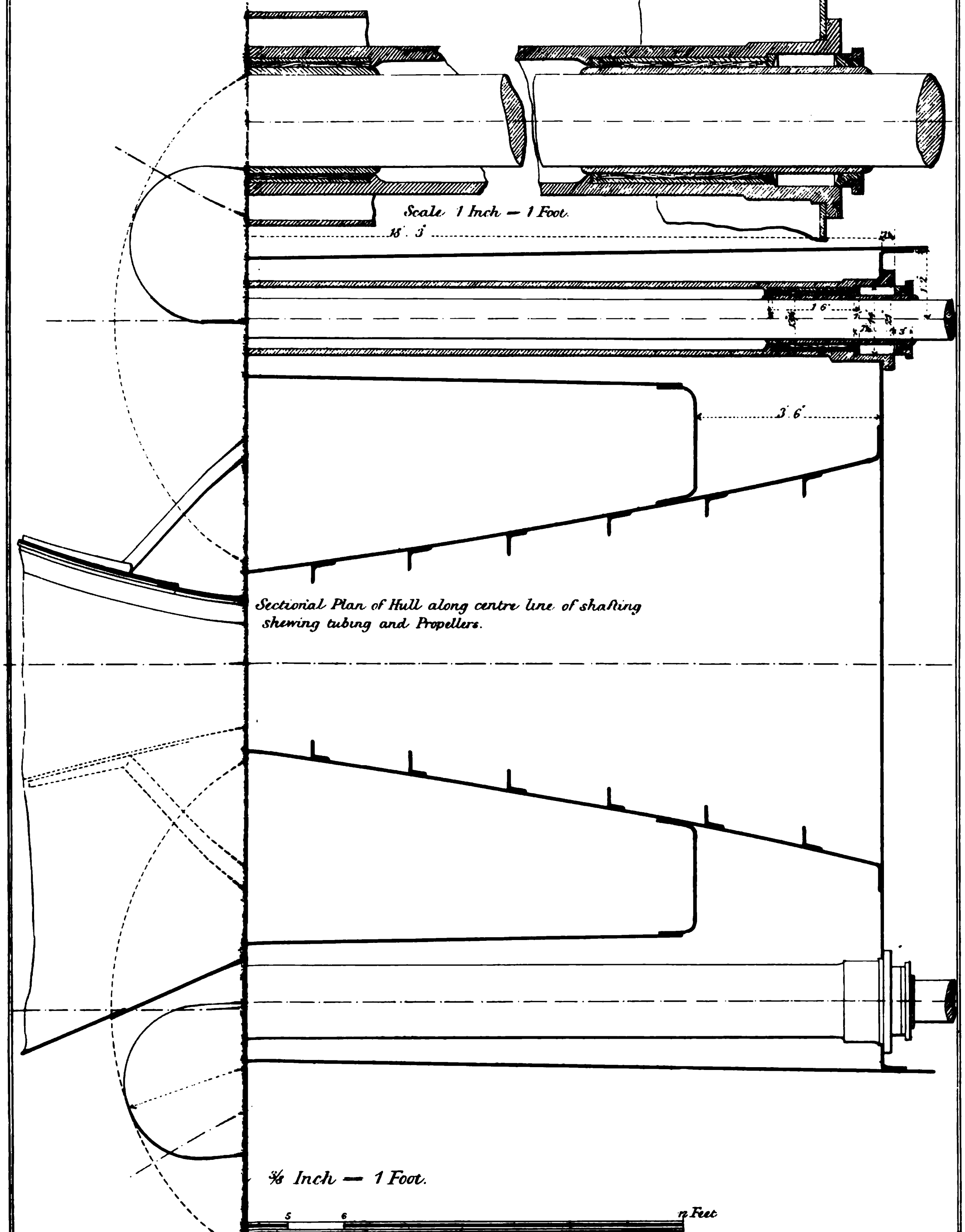
The propellers are the ordinary three-bladed type; both corners are considerably curved; the leading edge having the larger radii; the flattened form of the blade thus forms a striking contrast with that in Plate 13.

The boss is secured on the shaft by lateral and longitudinal keys, the former is at the aft end of the boss, and the latter forward, as shown in the sectional view.

As the rigidity of the stern tubing for twin screws is the most important acquisition, Messrs. Dudgeon sometimes add a strengthening portion to the bracket in the shape of a web which connects the tubing, throughout its length, to the hull, it being evident that where external stern tubes are used projecting to an extreme distance from the after parts of the body of the ship, such stern tubes should be connected together horizontally from end to end, as far as practicable, by means of framing and plating, bracing them together to and through the body; or, in some cases, in the place of two stern tubes being used, the screw shafts can be enclosed in chambers formed by plating, and projecting horizontally on each side of the stern of the ship or vessel; these chambers may form the stern tubes also for the two propeller shafts, and in the interior of the after parts of the body of the ship there can be a horizontal framing and plating corresponding in position with the outer plating above mentioned, by which conjoined construction great additional strength and stability are obtained; for example, immediately in front of the stern bulkhead the ribs and skin of the vessel can follow the curve of the mouth of the chamber, but abaft the bulkhead, the ribs and skin of the vessel may come between the chambers and thus are formed independently of them. The forged brackets are bolted to the side of the vessel and also support the after ends of the chambers, and the plating which forms the chamber is riveted along each edge to the side of the ship and at the back to the bracket. The horizontal bulkhead connects with the skin of the vessel on the inside where the platings of the screw shaft

M SHIP "RUAHINE"

CKET AND STUFFING BOX.



N P Burgh, Direx.

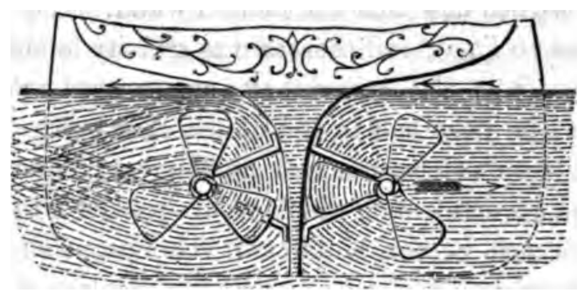
Newbery & Alexander Lith 43 Castle St Holborn

chambers connect it on the outside, so that a complete web is formed stretching from one propeller shaft to the other through the vessel. The chambers may be complete tubes, and in this case the web which connects these tubes to the vessel on each side will be single and will be riveted to the tube from end to end. A vertical bulkhead opposite the brackets is introduced to further increase the stiffness of the frame. It sometimes occurs that the tubes in which the screw shafts are encased are of gun metal, but more often of cast iron; they pass from end to end of the chambers, through the bulkhead in front, and through the eyes of the brackets at the back, and behind the eye of the bracket, each tube receives a screw nut, which securely fixes it by drawing a flange at its forward end against the face of the bulkhead. The propeller shafts are clothed with brass as usual, and pass through stuffing boxes at the front of the tubes and in bearings at their aft ends; most of these particulars are shown in the plate.

Nature of the Strains to be Resisted by the Supports for Twin-Screw Shafting.—Having proceeded thus far with the mechanical matters we will dilate a little now on the nature of the strains that result from the motion and position of twin screws, which will show also the resistance required from the supports and stern tubing. To put this in the most simple form for investigation, we will assume that a screw is fixed on the end of a shaft, that is supported at the opposite extremity, or at least some considerable distance from the screw, it is obvious that the weight of the shaft and its appendage will cause the former to deflect more or less according to the proportions of both of the details. Now, if the shaft is put in rotative motion the screw will revolve also, and its action will be more or less centrifugal; due of course to the radius and weight of the blades and their velocity. The shaft also will partake of this effect in proportion to its unsupported length and weight; so that as the centrifugal force is the main effect from the motion, the screw will not only revolve on its own axis, but also revolve around a circle whose diameter will be due to the weight and speed of the material, also to the strength of the shaft in proportion to its unsupported length. We may therefore justly conclude theoretically that the nature of the resistance required from the stern tubing and brackets is very nearly constant at all points or angles from the centre. In practice, however, this is not the case; because the shaft is held in position by the bearings; and, therefore, as the centrifugal force is resisted, the *weight* of the moving mass *rests* on the lower half of the bearing's diameter, which of course accounts for that portion of the surface wearing more than the upper; for obviously if the shaft were loose in its bearing, it would not only revolve on its axis, but also attain a centifrugal action, and thus the lower surface of the bearing would be relieved from the constant pressure on it.

Thus far we know the effect or nature of the strains that is due to the motion of the propeller; but as this is only a portion of the whole to which the supports are subject to, our remarks now follow on to the action of the water also.

We must here note the fact that the water has *no natural* motion below the surface currents, therefore if it is put in motion at that locality, the effect is derived from a mechanical cause.



Mechanical Motion of Water with Twin Screws.
Fig. 29.

As the most concise means of explaining the reality of this case, we have introduced the diagram, Fig. 29, which illustrates the stern end of a ship fitted with twin screws. The right hand propeller turns towards the hull, and the left hand propeller from it.

Now, there has been much difference of opinion amongst those learned in the subject, as to the *correct* way these screws should turn. One side argues that if the propeller turns towards the hull, or inwards, there must be a gain in the propelling effect, because the water at the side of the screw and immediately in front of it is driven between the hull and the screw, and thus a greater resistance for the blades is caused than otherwise occurs. Those of an opposite opinion urge the fact that this gain is counteracted by the increased skin friction of the hull, therefore what is gained is lost almost simultaneously, so that the final result is not affected at all by the matter held out as an advantage. There is not the least doubt that when the water is driven against the hull it must cause more friction than if it were motionless, because there is not only force in operation, but resistance also, which fact, to a great extent, is of weight in the above argument.

Next then as to the result, by turning the screw outwards, as on the left hand in the diagram, Fig. 29. Those who agree on this point contend that the screw does not put the water in motion nearly so much as when the screw turns inwards, because then it is *driving* the water against the hull, but now it is *lifting* it in that direction; or that one is gravity + force, and the other is force—gravity in effect; and, moreover, that the least amount of mechanical disturbance of the water produces the greatest fluid resistance for the screw, which, of course is the vital requisition.

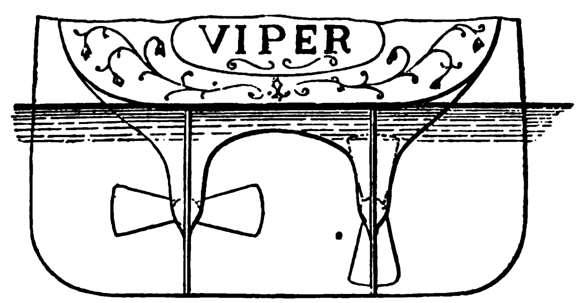
Having then settled what the water performs around the screw, we can next learn the effect in relation to the supports for the tubing. In the diagram, Fig. 29, it is shown that when the screw turns towards the hull, the water is put in motion in the same direction, and passes down between the tubing and the hull. Obviously then the water there acts as a wedge, and tends to push the tubing in the line of the central arrow; this support is therefore subjected to an outward thrust as well as a centrifugal action, which taken as a combination must produce a vibratory effect. And further, we may add, that this effect is not only common to the tubing, but is in connexion with the hull also; which although

it distributes the strain it weakens the stability of the main structure; being of course a disadvantage that should, under any circumstance, be avoided.

Passing from this, we refer next to the screw on the left hand, which is turning outwards, or from the hull, we see now that the motion water barely strikes the hull, because as we stated before, it has to *lift* it, and therefore as gravity is antagonistic to that operation, the volume inclines from the hull rather than towards it. The result of this in relation to the strains is that the tubing is little effected by the passing volume between it and the hull; certainly a small amount of vibration is incurred—due to the strain on the blades—but not nearly equivalent to that on the opposite side.

On comparing the relative motion of the two volumes, as shown by the diagram, it is apparent that the right hand volume is but partially circular, the curved portion being in contact with the hull, but on the left hand the moving volume is shown as almost entirely surrounding the screw, the strains produced therefore, are almost equal at all points around the centre of motion.

The arrangements of the details in connexion with the Supports for Twin Screws.—Knowing now what the strains are to which the supports are subject, we can better treat of the mechanical questions, and as a commencement, we refer to the arrangement of the supports fitted to or rather formed with the hulls of the *Viper* and *Vixen*. The propellers, it will be remembered, are hung in lifting frames, supported fore and aft, necessitating, therefore, double stern posts, as shown in side elevation in the Plate 13, and the end view by Fig. 30. This arrangement, although perhaps the strongest, is almost the worst possible for manœuvring purposes, as there are two walls of metal; between which a body of water is contained, and this body or volume must be put in motion as well as the ship, when the latter turns to port or starboard; being indeed a hull with double keels aft in the place of one as with the usual practice.

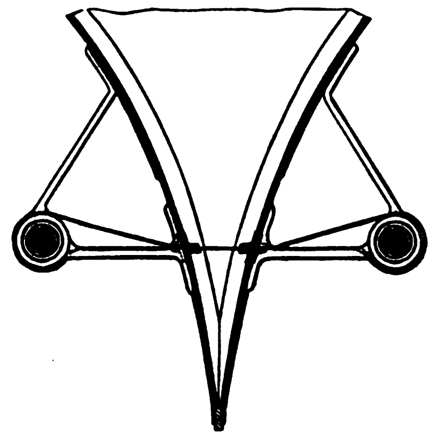


Stern End View of the *Viper* and *Vixen*—Gun Vessels in the Royal Navy.
Fig. 30.

The main object in view with this type was stability for the supports of the tubing, it being considered that if they were duplicates of that for the single screw, the end sought after would be obtained; which of course occurs, but certainly at the cost of extra expense of manufacture, more material, less buoyancy—where it is most needed—and the formation of surface aft currents which the twin-screw system is particularly adapted to avoid; in fact, it is not too observant to state that the double stern posts as those illustrated, possess more than all the evils of the single kind, with but part of the advantages.

A better arrangement for the supports is shown in Plate 14, where the stern tubing is not only built with the hull, but supported at the extremities by brackets of the shortest angles, also illustrated by Fig. 29, in page 104.

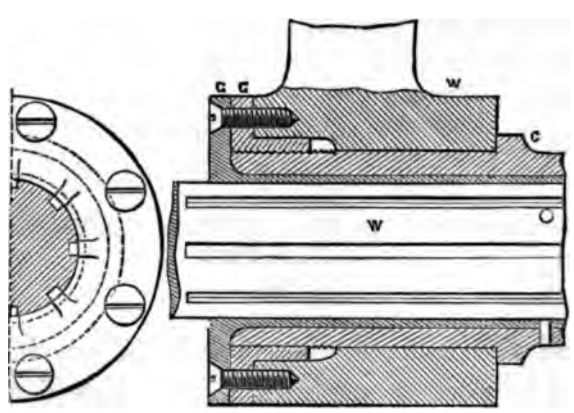
As before stated in page 102, webs of plating to connect the tubing for its entire length to the hull, are very suitable and likewise dispense with the brackets also, so that although brackets eclipse the double stern posts, they are superseded by the web connexion, which can be either of single or double plating, vertically or angularly secured to the hull. As a compromise, however, the arrangement by Messrs. Dudgeon is worthy of attention as illustrated by Fig. 31.



Messrs. Dudgeon's Web and Bracket Supports for Twin-Screw Tubing.
Fig. 31.

This arrangement is a happy medium both in principle and practice; the web is horizontal, also the lower arm of the bracket, while the upper is at an angle; this latter portion depending of course on the form of the hull. The object in view with this example is that the angles of the brackets shall be of the shortest lengths and the web also, connecting the tubing to the hull from the bracket to the aft bulkhead.

Having described the most modern practice for the supports, we will next turn attention to the details, beginning now with the shaft bearing and boss connexion. An arrangement by the author adopted with success, is illustrated by Fig. 32, which is formed of three materials: gun metal, G; wrought iron, W; and cast iron, C.

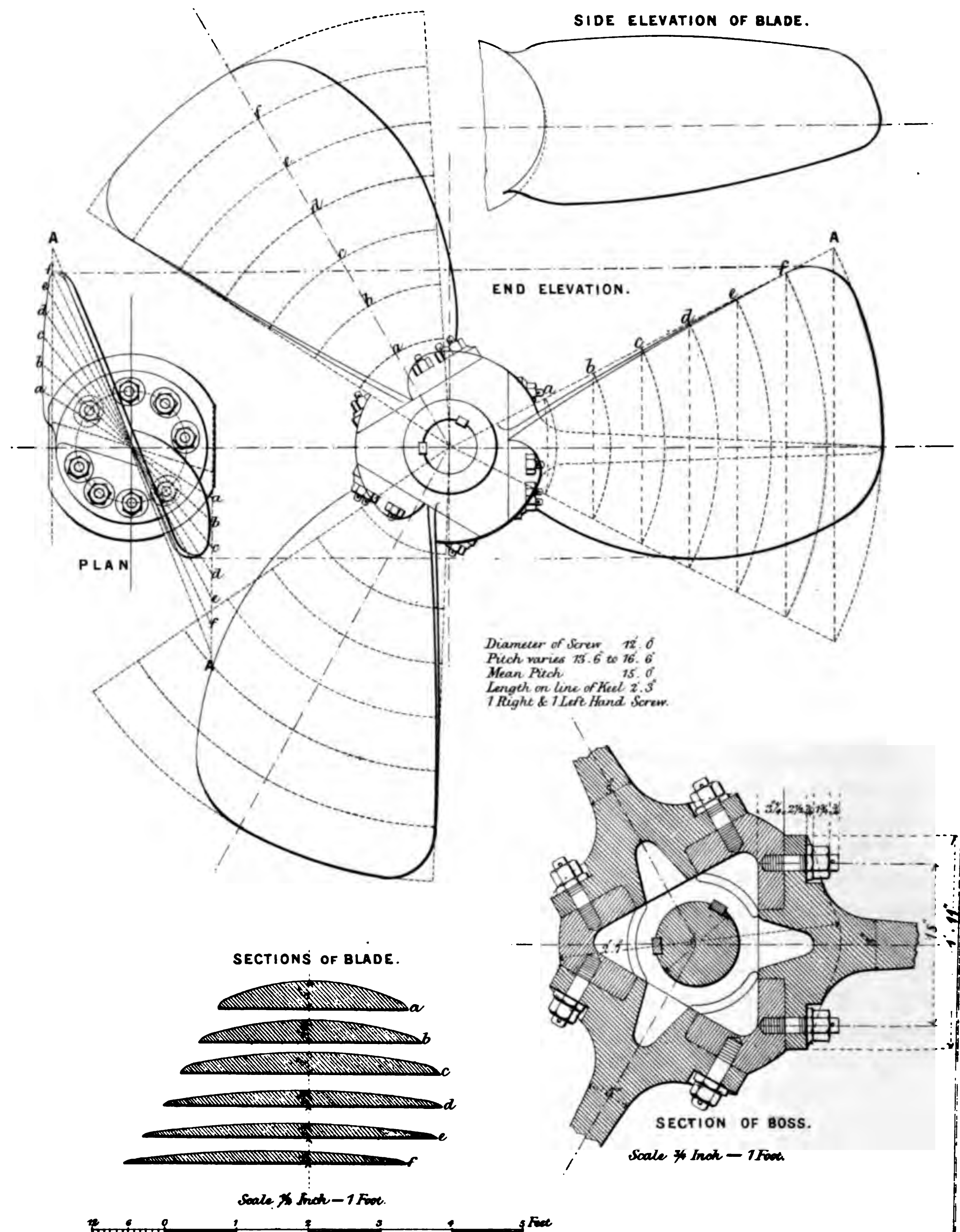


Burgh's Shaft Bearing and Bracket Connexion for Twin Screws.
Fig. 32.

The bracket is bored out to receive the tube and the nut at the extremity; the nut securing both the bracket and the tube; inside the latter is another tube of gun metal held in position by studs, which secure the nut also. The main feature is, that the shaft is channelled or grooved longitudinally to form water passages throughout the length of the bearing; the fluid acting as a lubricant. To ensure that a continual passage of the water occurs, the flange of the bearing tube is slotted similarly as the shaft is grooved—as shown in the end view—and the main tube beyond the bearing has holes in it, depicted in the section.

SCREW PROPELLER FOR THE GREEK GUNBOAT "KING GEORGE"

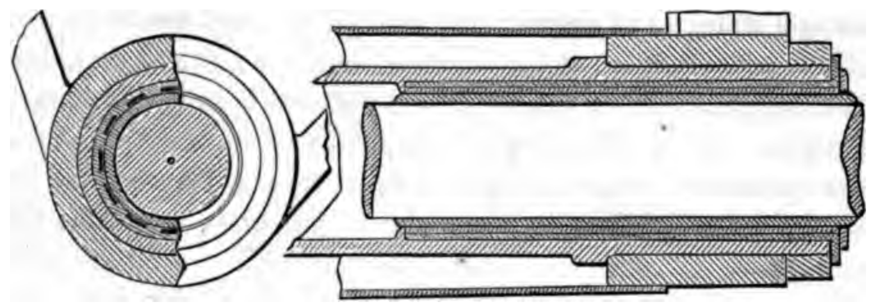
CONSTRUCTED BY THE THAMES IRONWORKS COMPANY.



N.P. Burgh. Drex.

E & F N Spon, 48, Charing Cross, London.

Another arrangement, constructed by Messrs. Dudgeon, embracing the principles entertained in the previous example, is shown by Fig. 33.



Messrs. Dudgeon's Shaft Bearing and Bracket Connexion for Twin Screws.

Fig. 33.

The bracket and tubing are connected as in the other case; but the bearing here is composed of lignum-vitæ strips with water spaces between them as shown in section by the end view. The tubing containing the strips is of gun-metal, also that directly in contact enclosing the shaft. To prevent any lateral disturbance two rings are secured by studs at the extremities of the main tubing and the bearing proper.

The shaft tubes for twin-screws, are generally as those illustrated in Plate 14, with a stuffing box formed at the inner or forward end, and a gland to correspond; the securing flange in connexion with the plating of the hull receives the gland studs as well as the securing bolts and nuts.

In cases where the lignum-vitæ strips are not used directly behind the stuffing boxes, the tube is lined with gun metal, and the shaft surrounded with it also for a certain length, thus forming a long bearing, while in other examples the gun metal around the shaft is omitted and wrought iron on gun metal forms the bearing.

Three-Bladed Twin-Screw Propeller, fitted to the Greek Gunboat "King George," by the Thames Iron Works Company. Plate 15.—This plate illustrates an end elevation of the propeller, which is the three-bladed type with adjustable blades; above this view a side elevation of one blade is shown. And the plan of that and the boss is on the left hand, directly under the elevation is the transverse sections of the blade and an enlarged section of the boss and flange connexions. As this class of propeller is becoming popular we shall describe in detail these three features; the formof the blade—means for its adjustment—and the mode of the flange connexion.

The form of the blade is not shown in flattened outline but in the end elevation only, the leading corner is curved with a large radius, and the following corner but slightly rounded off, the straight edges of the blade are not radial, as with other examples we

have described. It will be noticed that about this outline there is a dotted segment, which represents the imaginary form of the blade in this view before it was shaped as represented. The use of this segment is to produce the plan of the blade in connexion with a series of right angle triangles as shown; the method is this: the angle A A, is that of the top of the blade when it is set at the constructing pitch; the angle nearest the centre being that of the boss connexion; the horizontal distance between A A, is the length of the blade on the line of keel. The arc A is next described, and the length of its chord determined from the vertical length between A A, in the plan; from these points or limits the arc is connected by radial lines to the centre of the boss, and thus the segment is constructed as shown.

The arc *a* is then drawn, which is at the root of the blade; the chord of this arc is then formed and one half of it used as a radius in the plan to indicate the vertical positions of the angle *a*, which also is the angle of the blade at the root, at the same pitch as the top edge. Next the length on the radial line between the arcs A and *a* is divided into six equal parts and arcs are drawn to depict the divisions. Similarly the vertical space between the points A and *a* are divided, and the divisional points joined by angles or lines; then as the chords of the arcs A and *a* are equal to the vertical distances between A A and *a a*, so does the chord of the arc *f* refer to the height between *f f*, and the chord *e* to the space between *e e*, and so on consecutively; this method of projection is really the same in principle as that already investigated in Chapter 5.

Leaving now the connexion of the segment with the triangle, we must proceed next with the formation of the blade in plan; there are, of course, as already explained, two modes of doing this, either from the flattened outline of the blade or the end elevation. Supposing the latter to be adopted, it is but a matter of squaring down the points of intersection of one view to the other, as shown by the relation of the plan to the horizontal blade which the dotted connecting lines depict.

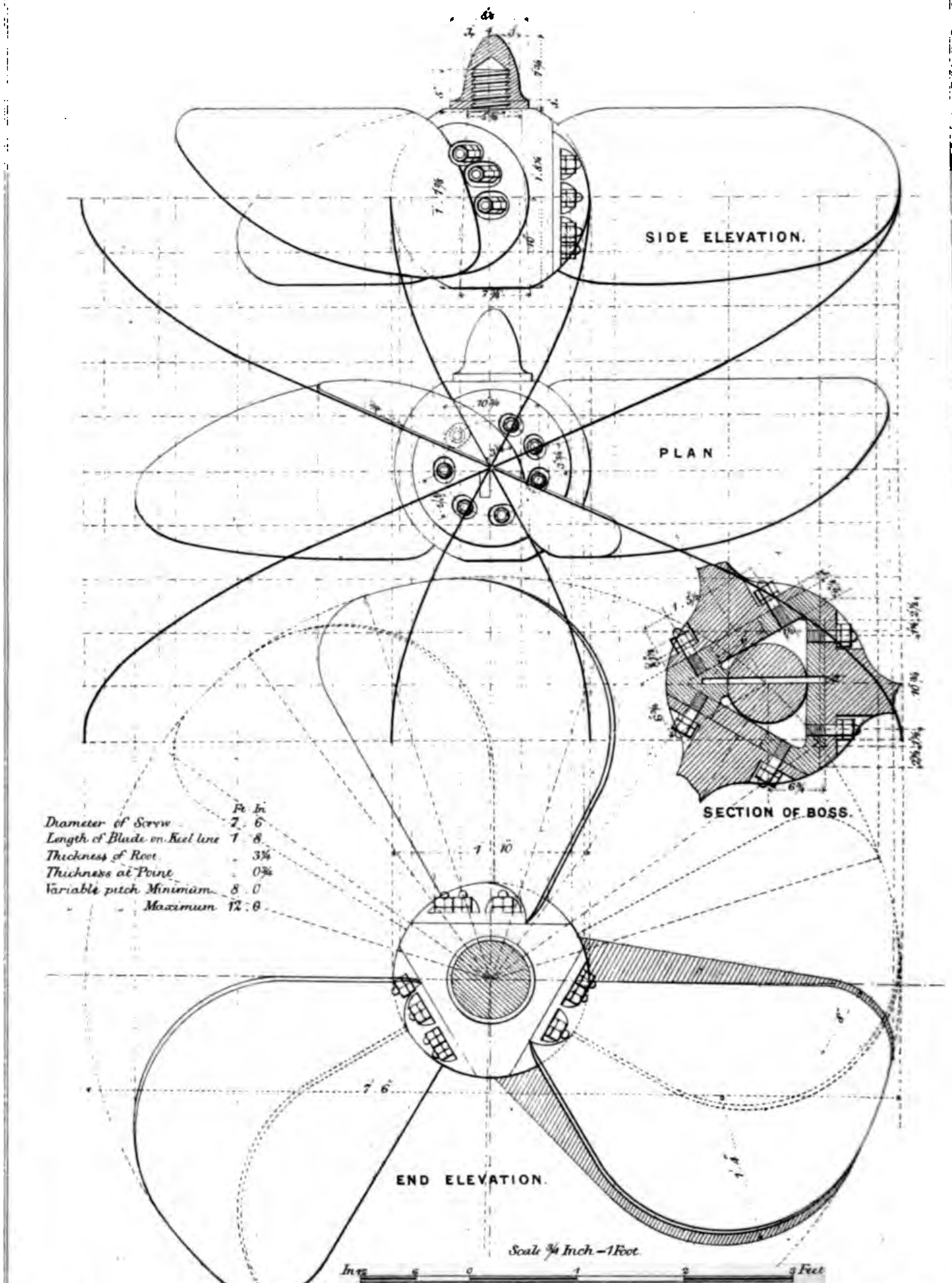
Although the flattened outline of the blade is not given in elevation, the extreme transverse sections are represented. The lengths of each portion are taken from the plan; being the angular distances between the intersections of the angles with the outline of the blade, on the line of the angles, also the only case where these lengths are utilized for geometrical purposes. The several thicknesses are taken from the sections of the length of the blade; the arc intersection determining the thickness for each.

The next portion of the present example which we have allotted for particular notice is the means for adjustment. The firm position of the blade on the boss is of course the first attainment in this matter, and secondly the adjustment.

To put this in a concise and practical form, an enlarged sectional view, of the boss together with the flanges of the blades, studs and nuts is shown at the foot of the plate, and the number of the studs are seen from the plan.

Plate 15 A

THREE BLADED TWIN-SCREW PROPELLER, BY N. P. BURGH.



N P Burgh Drw

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The securing effect is merely by screwing the face nuts sufficiently tight on the flange, and then preventing looseness by the deep lock nuts on the outside; a pin passing beyond this through the stud further sustains the connexion.

The adjustment of the blade is produced by slackening the nuts, and by main force turning the blade in the direction required; the stud holes being elongated sufficiently to allow for this movement in either direction.

The third notice is the mode of the flange connexion. As a brief preface to this, we may mention a little about the requisitions important to this subject. The strain imposed on the root of a blade may be considered as that for a beam supported at one end and loaded at the other, so that the longer the beam or blade, the load being constant, the greater the strain outside the support or at the root. We know from this, then, that the *surface* for the connexion of the blade with the boss should be fully considered as well as the diameter or area of the securing studs.

In the example before us some attention has been paid to this matter in the shape of a fitting projection and a wide flange, both of which tend greatly to sustain the blade when in motion, and relieve the studs from the total shearing strain.

The boss is secured on the shaft by two longitudinal keys, being the practice by many engineers, who deem that mode sufficient for the purpose.

Three-bladed Twin-screw Propeller, by N. P. Burgh, Plate 15a.—This example is one of a pair fitted to a ship whose engines and boilers were designed by the author; the illustrations in the plate are the end view, the plan, and the side elevation, with a section of the boss and the flange connexion.

As the correct representation of these views have been faithfully depicted, we will dwell a little on the method adopted to produce this. The helices of the top edge and root of the blade were first formed by the ordinary means, as shown by dotted lines; the diameter of the boss was then drawn, and next the flattened outline of the blade; the next question settled was the length of the blade on the line of keel, which also determined the angular limit of the blade in plan; from these two points the outline of the end view of the blade was known, and the contrast between it and the flattened form is depicted by the shaded spaces at each edge.

The outline of the two blades in plan, projecting from the boss, are squared from those at an angle in the elevation; of course more points for the position of outline are used than shown; but they are all alike in principle. Similarly, also, the side elevation of the blade is produced, the end view being shifted to suit the most ready means for projection, as shown by dotted lines.

Having settled the geometry of the blades, we will next attend to the mechanical arrangement. The blades are adjustable, and secured by studs and nuts, as shown in the plan, and the sectional view of the boss and its connexions. It will be noticed that the

modes of the flange connexions are not all the same, two being duplicates, and the third a separate arrangement of surfaces; the cause for this is that the securing key of the boss passes laterally through the shaft, and thus one flange seating must be formed accordingly; the boss is further secured by the nut at the aft end, which is keyed laterally also. The flange nuts and studs are much the same as those in the last example, with the holes in the flanges elongated, to suit the shifting of the blade.

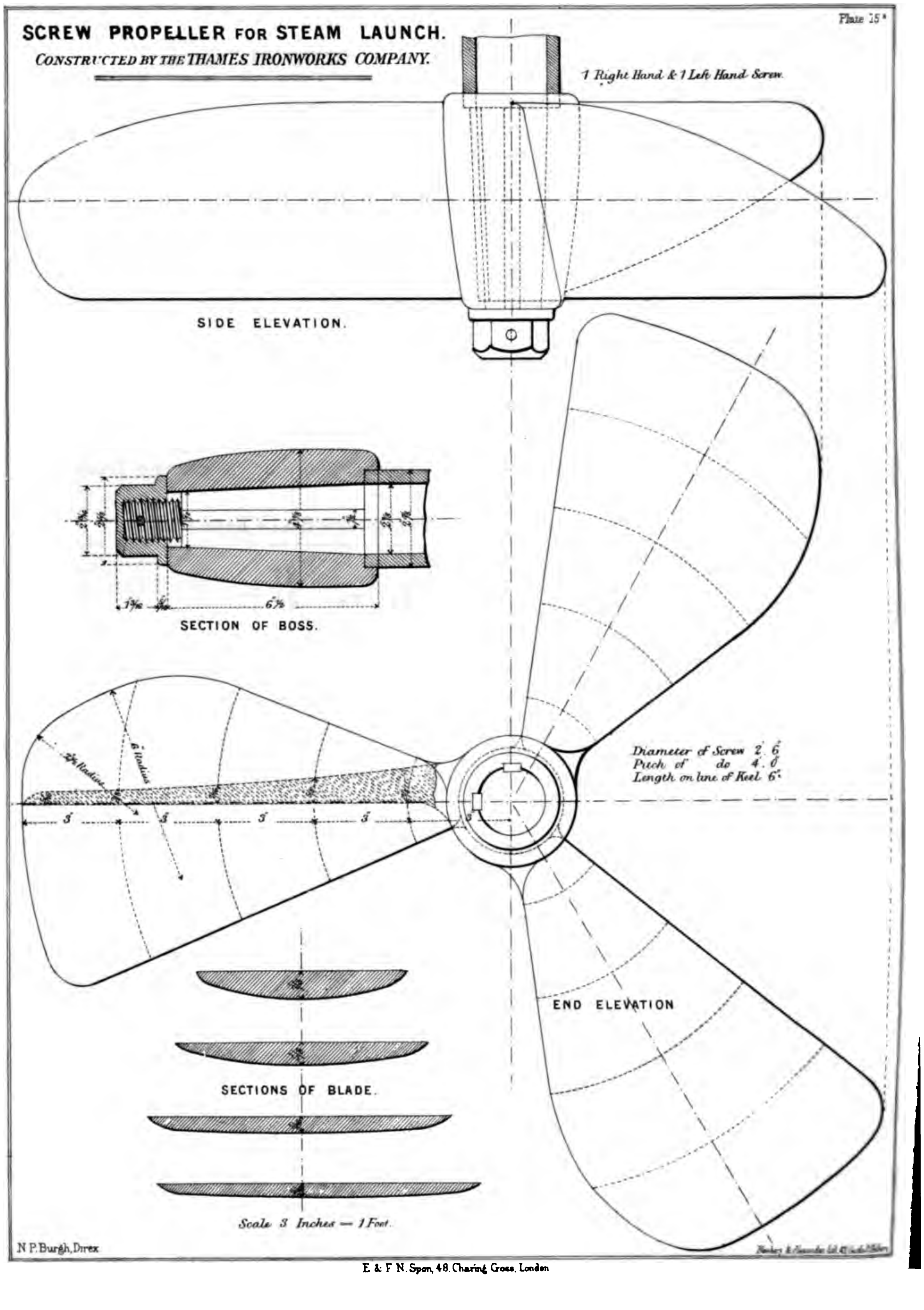
TWIN SCREW-PROPELLERS FOR STEAM YACHTS AND LAUNCHES.—Although two classes of boats are stated in this heading, we may mention, to begin with, that the propellers for each are alike, as a rule, with few exceptions, which are, in consideration of the draught of the hull and the tonnage of displacement. Of course, whether the hull is for a yacht or a launch, the proportions for the propeller should be that to attain the greatest speed for the hull with the least power exerted; so that in dealing with this matter the distinction between the yacht and the launch, when both are of the same dimensions, is not worth alluding to for the present purpose in view.

The propellers for yachts now mostly in use are either two, three, or four bladed, and the diameters range from 18 in. to 3 ft.; in some cases 3 ft. 6 in.; but seldom more than 4 ft. The blades and boss are generally in one casting; here and there adjustable blades have been preferred; but, as their area is small and the speed is great, there is not much advantage derived from altering the pitch a few inches more or less, to say nothing of the first cost, and trouble after, to be able to do so. When an owner of a yacht requires speed, with the least liability for the break down of the propeller, the more simple that instrument is the better; for it might often occur that the time expended in altering the pitch would never be made up by the result of that operation.

The propellers for "launches" are usually about 2 ft. 6 in. in diameter, and 3 ft. to 4 ft. pitch, with three or four blades cast with the boss. As the arrangement of the boiler and engines for these boats have received considerable attention, by the leading firms, to reduce the weight of material, &c., we will explain how this is effected before proceeding to other matters in connexion with the present subject.

Messrs. Penn and Messrs. Maudslay adopt locomotive boilers with the steam dome over the fire box. The engines are inverted direct acting; single piston rods with bracket guides beyond the connecting-rod pin. Messrs. Penn situate the slide valves between the cylinders, while Messrs. Maudslay prefer to put them fore and aft. Each pair of engines are secured to the shell of the boiler at the fire-box end, so that the stoker can be the engineer in charge also.

Messrs. Rennie prefer a single inverted engine for each screw, direct acting with double side guides for the piston rods. The boiler is the *return* tubular type, therefore the chimney is over the fire door, the engines are each secured to the sides of the boiler at its aft end, instead of forward as by Messrs. Penn and Maudslay. Another



E. & F. N. Spon, 48. Charing Cross. London

novelty with Messrs. Rennie's engines is that they are not only high pressure—as the other examples referred to—but also surface condensing; the condensers being secured to shell of the boiler about midway of its length on each side. The circulation of the condensing water is produced by centrifugal pumps, driven by spur gearing secured on the screw shafts.

The Thames Ironworks Company, have lately built a steam launch with engines and boiler for the Spanish Government. The boiler is the locomotive type, and the engines are inverted direct acting; the piston rods having slipper guides, the slide valves are between the cylinders, both pair of engines are secured to the sides of the fire box, as the other arrangement here noticed.

The following Table of the main dimensions of twin-screw steam launches, lately added to the fleet of the Royal Navy by the three firms: Messrs. Penn, Maudslay, and Rennie, is of important interest; also the example for the Spanish Navy by the Thames Ironworks Company:

PARTICULARS AND PERFORMANCES OF TWIN-SCREW STEAM LAUNCHES.

Name of Firm.	Diameter of Propellers.		Pitch.		Length on Line of Keel.	No. of Blades.	No. of Engine Cylinders for each Screw.	Diameter of Cylinder.	Length of Stroke of Piston.	No. of Revolutions of Screws.	Length of Launch.	Breadth.		Depth.		Speed in Knots per hour.
	Ft.	In.	Ft.	In.	In.			In.	In.		Ft.	Ft.	In.	Ft.	In.	Knots.
Messrs. John Penn and Son . . .	2	6	4	0	4	4	2	5	6	300	42	10	6	3	9	8·5
Messrs. J. and G. Rennie	2	6	3	6	3½	4	1	6	6	327	42	10	11	3	10	8·054
Messrs. Maudslay, Sons, and Field .	2	6	3	0	3	4	2	5	6	315	42	10	6	3	9	7·25
Thames Iron Works Company . . .	2	6	4	0	6	3	2	5½	6	350	41	11	0	5	0	8·548

The following are the weights of the boiler, engines, propellers, fittings complete, and the water in boiler:

	Tons.	cwts.	qrs.	llbs.
Messrs. Penn's	3	4	2	0
„ Rennie's	3	13	1	0
„ Maudslay's (exclusive of propellers, tubing, and shafting) .	2	7	0	0
Thames Ironworks	5	1	3	2

TWIN SCREW-PROPELLER FOR STEAM LAUNCH, BY THE THAMES IRONWORKS COMPANY, PLATE 15B.—This Plate illustrates side and end elevations and sections of the boss and blades of a three-bladed propeller lately fitted to a steam launch. The leading corner of the blade is curved with two radii, and the following corner with only one of much less dimension. The shape of the section lengthways is shown in dotted lines, and the transverse sections in full lines below. The mode of securing the boss on the shaft is by two longitudinal keys and a nut on the shaft at the extremity of the boss.

An example of a four-bladed screw-propeller for a launch is shown by Plate D, opposite to page 12 of this work, and by referring to it a comparison can be formed at once with this in Plate 15B. The main difference in these two examples is in the form of the blades and their length on the line of keel; the diameters are alike, and only 6 in. difference in the pitches.

The stern tubing for the screw shafting for yachts and launches is generally a gun-metal tube, with a flange to secure it to the hull, either by bolts and nuts, or rivets; the aft extremity is sustained by twin angular or single arm brackets, according to the lines of the hull and the position of the screw; the tube is often bored throughout its length, for the shaft to have a long bearing, the shaft being covered with gun-metal, as shown in the two Plates referred to. The stuffing-box is the ordinary kind, with the gland inside the hull, and adjusted by bolts and nuts.

Although we have alluded especially to yachts and launches, we may add, as a conclusion to this chapter, that there are boats of much smaller dimensions than those recorded fitted with screws, boilers, and engines; for instance, the new pinnace belonging to Messrs. Penn is only 26 ft. long, 5 ft. 4 in. beam, and 2 ft. 5 in. deep; the screw-propeller is 2 ft. in diameter, 2 ft. 6 in. pitch, and has three blades, and when working at 360 revolutions per minute the speed of the hull was 7·5 miles per hour, the machinery, boiler, and water weighing but $8\frac{1}{2}$ cwt., and the hull 8 cwt.

CHAPTER X.

GENERAL REMARKS ON THE TWIN-SCREW SYSTEM.

BY CAPTAIN T. E. SYMONDS, ROYAL NAVY, CHAIRMAN OF THE LONDON ENGINEERING AND IRON SHIP-BUILDING COMPANY.

IT was with some diffidence, but very great pleasure, that I acceded to Mr. Burgh's request to contribute an article to his valuable work on this deeply interesting and important subject. I did so with the hope that my remarks might be of assistance in arriving at a correct estimate of the advantages of the system by a relation of facts that have come under my notice, adding a few suggestions on the different methods of construction that have occurred to me in practice.

My acquaintance with the twin-screw system commenced about that period when naval architects of eminence had determined that a certain increased proportion of length to breadth was absolutely necessary to attain high speed and sea-going qualities in weight-carrying ships, more especially in those having a combination of steam and sails. This led to the abandonment of the type of ship introduced by Sir William Symonds, and the adoption of those long screw frigates, whose inability to manœuvre in narrow waters, either under steam or canvas, became so notorious. At such a time, when theories of every description were started to remedy this defect, it was surprising that a system offering so simple and practical a solution of the difficulty should have been disregarded by the naval architect. As a seaman, I at once became impressed with its value when first introduced to my notice by the late Mr. Richard Roberts,

and subsequently, under his auspices, my opinion was confirmed by a more intimate acquaintance with its mechanical advantages, especially when applied to large ships. Since which time I have been a persistent advocate of the system, and more particularly that application of it which he originated, and which I still believe to be the simplest and most efficient. In the course of this article I have brought forward several inventions of my own that have been suggested by experience, which I trust may be found to contribute to the further development of the principle.

The only object that appears to have been contemplated in the early application of the twin-screw system was a greater development of engine power in vessels of light draught than could be attained with the single screw, the remarkable manœuvring power, and other capabilities being either overlooked or unappreciated.

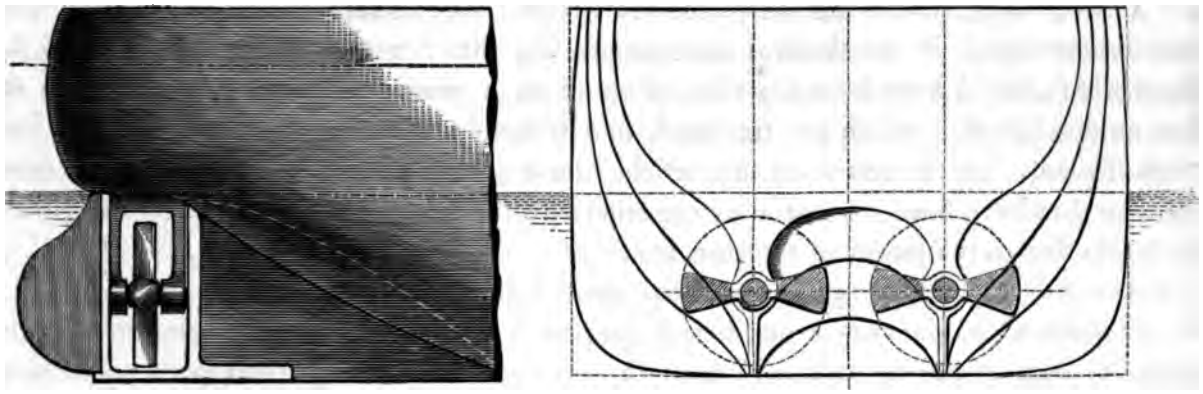
At the discussion of my first paper on this subject, at the Royal United Service Institution, in 1862—which was based on practice in 1859—the existence of these qualifications was absolutely denied by those who, having constructed vessels with *two screws*, were deemed "authorities," their opinions thus carried undue weight, and considerably retarded the adoption of the system for a time.

I mention this circumstance merely to show the state of opinion, even at that period.

Passing over a host of objections which have been raised from time to time by prejudice or scepticism, such as complexity of engines, increased friction, loss of space, difficulty of construction, &c., all of which have been scattered by recent practice, I consider the principal obstruction to its adoption was the commercial inconvenience involved by the change of patterns of engines, added to the usual disinclination to depart from old institutions and to abandon pre-conceived notions of excellence. This, however, is at last overcome; the first engineering talent has been applied to the design and arrangement of twin-screw engines, and naval architects, both at home and abroad, have at last deemed the matter worthy of their serious consideration.

We are indebted to the ability and enterprise of the Messrs. Dudgeon for the first application of this system on a *large scale*, in their successful endeavour to produce a vessel combining all the requirements of the blockade runner, which gave great prominence to the subject, and established its value for ocean navigation. It affords me very sincere pleasure to add my testimony in confirmation of many of the facts recorded by them in this work.

It is very unfortunate that the examples furnished by the Admiralty practice have not been equally successful; but no one conversant with the subject ever expected a satisfactory result from the designs adopted in their construction. So unfavourable, indeed, are they, as to have revived doubts, which were even cited in Parliament with a view of preventing the further adoption of this valuable system.

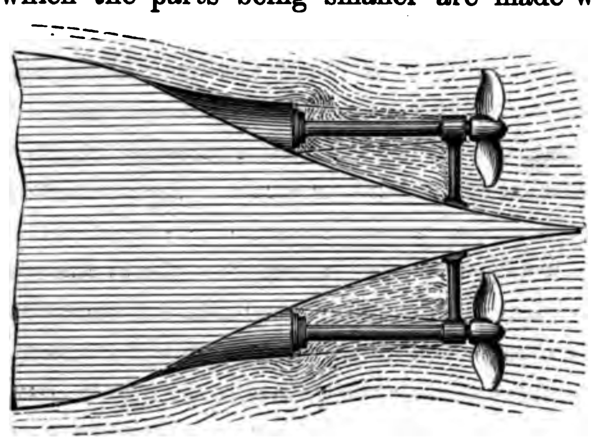


Elevations of the after body of H.M. Gun-vessels *Viper* and *Vixen*.

Fig. 34.

Figs. 34 and 35 represent the designs referred to, the former being that adopted in the *Viper*, *Vixen*, and *Rocket*, the latter being one of the composite gunboats just completed.

It appears that notwithstanding the many successful examples on record, doubts are still expressed as to the applicability of this system to ships of large dimensions and deep draught. I have always contended "that the larger the ship the more will the advantages of the system be manifested," principally for the following reasons:—Division of the ponderous engines, in which the parts being smaller are made with greater perfection, more portable if requiring repair and less liable to injury when in motion. Deeper immersion of the screws, which working under a greater head of water will produce a more uniform and better effect; less possibility of being lifted, and less liability to foul, or to be lifted out of water in pitching. This duplex arrangement enhances the safety and efficiency of the ship, which in case of a break down of one set of boilers or machinery, has still sufficient power remaining to ensure her safety; whereas should a similar contingency occur to a single-screw ship she would be totally disabled as a steamer; and be at the mercy of the wind and sea.



Plan of the latest Method adopted by the Admiralty for supporting the shafting of Twin Screws as fitted to the gun-vessel *Rocket*.

Fig. 35.

A most conclusive example in illustration of this has lately been afforded in the total break down of the *Atrato* paddle steamer of 800 horse power. Length 336·6 ft. Breadth 40·9 ft., and 1969 tons, which, being of such recent occurrence, cannot fail to have its due weight. Compare the result of this untoward and costly accident with that of the *Ruahine*, a twin-screw steamer of 350 horse power, and 1596 tons. In her case both engines broke down during a gale of wind on her passage home from the West Indies, but being precisely similar in all their parts, one engine was made perfect, and the ship performed her voyage home at a speed of seven knots.

The difficulty of manœuvring, if not the positive unsafety of long single-screw ships in narrow waters, has led to a return to the old type of short long-heeled ships in Her Majesty's service, which though necessarily turning in a shorter space, do so at the expense of sea speed, weight carrying capabilities, steadiness of platform, and sea-going qualities.

The balanced rudder has been added as a further means of turning quickly, which, though acting well under steam, is not to be relied upon under canvas, and being a more delicate instrument than the ordinary rudder, is more liable to injury. But all these concessions and additions, involving complexity and expense, fail to attain that unerring certainty of turning in either direction *on the centre* that is secured by the twin-screw system, wherein, if a difficulty arises, the propelling power becomes the steering agent, which acts *instantaneously on the ship*, whether at rest or moving; whereas with the single screw, motion is absolutely necessary to steerage, and even then the action is by no means certain. As much misapprehension exists with regard to this "turning power," it may be as well to observe that in action or in narrow waters, where the ship's course has to be reversed suddenly to avoid danger, or outmanœuvre an antagonist, the power of pivoting on the centre possessed by twin screws is invaluable and utterly unattainable with a single screw. It is the "turn half round" end for end, or winding, as it is termed by sailors, that is so valuable; the "whole turn" being obviously unnecessary. A single-screw ship must of necessity describe a circle in performing this evolution, which may be impossible in narrow water, whereas a twin-screw ship performs the evolution on her centre, keeping "end-on" to her antagonist, being under such perfect command of her screws, that her head may be turned to starboard or to port at will by reversing the engines, which act instantaneously and unerringly on the ship's head. The *Naugatuck*, American twin-screw gunboat, relied entirely on her screws for pointing her fixed gun, making capital practice. I exhibited this manœuvre to the Lords of the Admiralty in July, 1864, in the *Itaperica*, twin-screw, built by Messrs. Dudgeon, which they kindly lent me for the purpose. It has recently been put forward as a *novelty* in the *Nautilus!!*

Did space permit, numerous instances might be cited in corroboration of the important power of steering and manœuvring by means of twin-screws. A remarkable example was afforded in the *Ruahine*, when going down the Thames at a speed of eleven

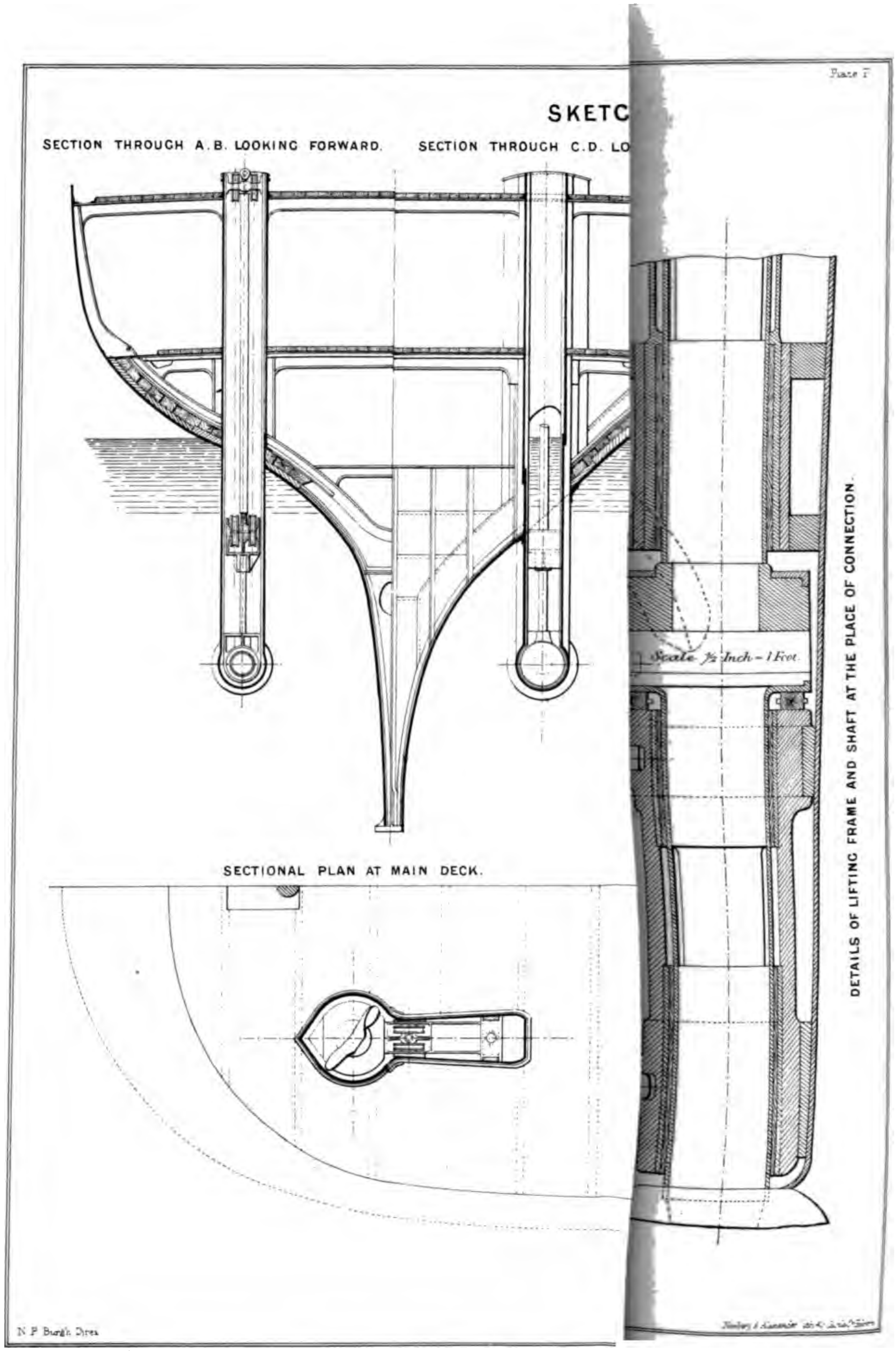
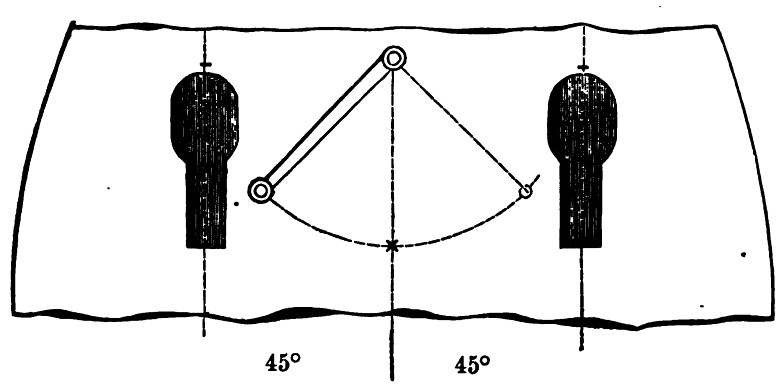


Plate F
SKETC
SECTION THROUGH A.B. LOOKING FORWARD.
SECTION THROUGH C.D. LO
SECTIONAL PLAN AT MAIN DECK.
DETAILS OF LIFTING FRAME AND SHAFT AT THE PLACE OF CONNECTION.
Scale ½ Inch = 1 Foot.
N. P. Burgh Direx

knots, wind aft, her course was suddenly stopped, and her head brought up the river in two minutes by reversing one screw. After picking up a boat, the opposite screw was reversed, and her head turned down the river again. This evolution is unparalleled in the annals of steam-ship performance, and would never have been attempted by a ship with a single screw under similar circumstances. Her length is 288 ft., and the space she had to turn in barely 250 yards.

Although we are constantly reminded that a few turns of a rope's-end, and other contingencies equally contemptible, will inextricably foul the largest screw-propeller unless fitted to lift—its only chance of being cleared—it has been deemed advisable to dispense with lifting the screw in many instances. This I consider a fatal mistake in the construction of a ship of war, and is a sacrifice involved by the single-screw system that, I believe, will be attended with serious consequences, either in action or on a lee shore. We are informed that this plan has been adopted with a view of giving greater strength to the after-body, and to enable tillers to be fitted instead of yokes, which have proved inadequate for steering these enormous fabrics. It was to remedy this serious defect that I designed the method for lifting twin screws, shown in Plate F. The screws are lifted through apertures in either quarter, the central strength of the ship remaining unimpaired. There being no space in the deadwood, as in the single-screw ship, the water flows direct to the rudder instead of escaping through the aperture. The steerage is therefore as perfect as in a sailing ship; the long tiller is adopted without any sacrifice, and works freely between the well trunks, as shown by Fig. 36. No additional rudder



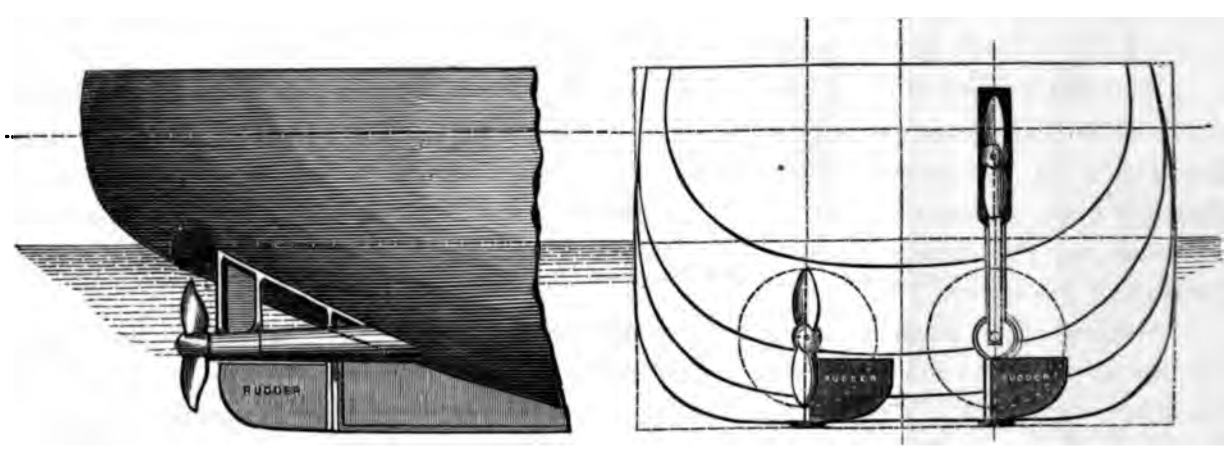
Plan of position of Screw apertures with the Tiller between them.
Fig. 36.

surface is required, or application of steam, or hydraulic power to actuate it. This arrangement for lifting twin screws may be described as follows: The screws are fixed upon short shafts, which are enclosed in long bearings composed of two half carriages. These carriages are enclosed by strong vertical guide frames, which attach the ends of the

tubes surrounding the main shafts to the bottom of the ship, forming a support to the whole. The space between these guide frames is strongly plated, forming trunks up which these carriages slide when the screws are being lifted, the screws passing up into their respective wells on either quarter. An ordinary "cheese" coupling is fitted to each of the inner ends of the short screw shafts, the corresponding halves being fitted on the ends of the main shafts, which are led through a transverse bulkhead within the tube, and fitted with a stuffing box.

Many difficulties occurred to me in designing this arrangement for lifting overhung screws, which are unnecessary to explain in these pages. They have, however, disappeared by the experience gained in the *Far East*—a ship of 1300 tons, fitted on this principle by Messrs. Dudgeon—during several voyages to India and China, when they answered perfectly. I have therefore every confidence in the strength and general efficiency of the arrangement, and believe it to be the simplest and least obstructive to speed or manœuvring that can be devised for "lifting screws" in single keeled ships. I am indebted to the courteous assistance of Messrs. John Penn and Sons for the mechanical drawing of my invention for lifting twin screws as shown in Plate F.

I originally designed this for ships fitted with two keels, and two rudders, on the late Mr. R. Roberts's principle—a method I prefer for reasons hereafter stated. On this plan the screws are also overhung, being supported and attached to the hull on either quarter in the same manner as shown in Plate F. The central deadwood and rudder being substituted by two keels which are fitted under the tubes or trunks of the screw shafts, and are continued as far as may be necessary, as shown by Fig. 37. They may be con-



Elevations of the after body of a Gun-vessel fitted with lifting Twin Screws, on Capt. T. E. Symonds' principle.
Fig. 37.

structed like the ordinary bilge keels applied to ships of war, or in the form of cellular girders; the rudders are attached to the after extremities of these keels, and are actuated

by posts keyed into the rudders which are led through pipes clear of the shaft surmounted by a stuffing-box, they are geared together and act in unison or separately, as required. These posts can be readily withdrawn in case of accident to the rudder.

To prevent mistakes, I may mention that there is no point of similarity between the arrangement just described and that adopted in the *Viper*, *Vixen*, and *Rocket*, shown by Figs. 34 and 35, in page 115, beyond their having two rudders and two screws. The "designer" of those former vessels having so far recognised the principle I have advocated since 1862 in preference to the "bracket and single keel." My arrangement is equally strong, less complex, and lighter, with less area of resistance to turning, than the *Viper* and *Vixen*, as may be seen by a reference to Fig. 37; the after sternposts and portions of the deadwoods as applied in those vessels being dispensed with, and there is also a free course left for the water through the triangular space before the lifting frame, also shown by Fig. 37. The rudders and steering gear being at a much greater depth, are less liable to casualty, and being constantly submerged, the working area is constant. The efficiency of this description of rudder has been amply proved for many years in the single-screw steamer *Caroline*, employed in laying sub-marine cables.

This form and arrangement obviates the necessity for the device resorted to in some single-keel ships for protecting the rudder head by an armour-plated "knuckle," which adds greatly to the weight of the after extremity, and being submerged retards the delivery of the water, and acts injuriously on the speed of the ship.

As twin screws act instantaneously as a steering power upon a vessel when at rest, the objection to the screw abaft the rudder vanishes, it being in all other respects advantageous. Vibration is unknown in those ships having the screw in that position, and it is less liable to foul; if fouled it is more easily cleared.

Now the designs of the *Viper* and *Vixen*—Fig. 34—are in fact an adaptation of the sterns of two single-screw ships to one hull, entailing an arch or "tunnel" between the deadwoods that reduces the displacement and involves increased weight and distortion of the after body, whereas the after body in my ship is elliptical, which is the simplest of construction, the strongest, most buoyant, and the form best calculated for a clear delivery of the water.

Although the method of supporting the screw-shaft with "brackets" has been adopted to the exclusion of all other methods, by Messrs. Dudgeon and other builders, it has always appeared to me an unmechanical expedient which certainly invites fouling, and, to some extent, must be an obstruction to the speed of the ship. The two arms of the bracket are immediately before the screws, they must therefore displace or disturb the water to a considerable extent just as it reaches them. The advocates of the bracket system admit the imperfection of this application by stating that "they make the brackets so as to offer as little resistance to the water as possible."

The arrangement of the bracket system, as applied in the composite gunboats before referred to, is open to still further objection; the tube or trunk represented by dotted lines by Fig. 35, in page 115, being terminated abruptly as shown, which causes an additional obstruction of a serious and compound nature, *i.e.*, not only by creating a great "disturbance" in the water previous to its reaching the brackets, where it is again churned up, but by creating dead-water, or drag, in the wake of those abrupt terminations of the tubes.

Moreover, these tubes have been found in practice to conduce very materially to the general steadiness of the ship.

I have always advocated the adoption of the "gusset-plate," or "web" in preference to the "bracket," but although highly commended, *it has never been adopted.* By this arrangement the attachment extends along the entire length of the tube, and is consequently distributed over a larger surface of the body of the ship, thereby imparting additional strength and rigidity to that part of the body acted upon more directly by the motion of screws, instead of being secured at a point at the extremity of the tube, as in the bracket system; there is also less resisting surface opposed to the speed of the ship, less liability to foul, and the flow of water to the screws less impeded than by the brackets, the only resistance being due to friction.

Plate G is an illustration of this arrangement in a composite vessel, having non-lifting screws, in which the gusset plate, or web stands at an angle of about 45° with the vertical plane of the ship, which is the shortest distance between the points of attachment, and therefore the strongest, and is the most favourable for the admission of the water to the inner blade of the screw; it will also contribute to the stability and steadiness of the vessel. In fact, these webs may form continuations of the bilge keels usually fitted for that purpose.

The ends of the tubes that enclose the bearings of the shafting are fitted with metal caps which retain the outer ends of the planking or sheathing, having a flange overlapping to cover or close the space or joint between the bosses of the propellers and the bearings, so as to prevent objects being drawn in that may interfere with the action of the screws, the fore ends of the bosses of the screws being so formed as to facilitate this object. A similar arrangement can be carried out in an iron vessel, as shown in Plate G.

It may prove preferable under some circumstances to perforate these webs, or to construct them with lattice work, in which case although the "turning" from the ship would be facilitated, I believe a better result in speed would be obtained without the perforation, as in that case there would be no obstruction to the passage of the water, the same argument applies to the triangular space left between the lifting frame and bottom of the ship, as shown in Plate F, and Fig. 37.

Assured of the advantages of this system, I submitted the design, as shown *in*

Plate F, to the Admiralty for fitting it to the gunboat *Rocket*, then building at the yard of the London Engineering and Iron Ship Building Company, Limited, which was approved, and permission was given to apply it; however, the construction of that vessel was too far advanced to take advantage of it when the intimation was received.

With regard to the difference of opinion which exists as to whether twin screws should turn "inwards" or "outwards," my experience leads me to prefer the "outward turn," whether in single or double-keeled ships. In single-keeled ships, the rudder being abaft the screws, the streams or columns of water delivered by them would be convergent on the rudder, and thereby increase the steering power; whereas on the "inward turn" the stream would be divergent. Secondly, on the outward turn the columns of water acted upon by the screws would move in the natural course of replacement, thereby tending to give additional support to the stern; whereas the inward turn would divert that stream from its course, and tend to deprive the stern of its necessary support.

I submit that the method of construction I have referred to and illustrated by Fig. 37, at page 118, is free from the objections raised on both sides of the argument. The deadwood being removed, an uninterrupted column of water is admitted as directly to the inner as to the outer blades of the screw, thus producing uniformity of action, which tends to reduce vibration; and there being nothing to interfere with a clear delivery of the water, a good mechanical result may be anticipated.

It is to be regretted that the opportunity afforded in the construction of the six gunboats lately built for Her Majesty's service should not have been taken advantage of to decide so important a question by experiment, especially as it might have been done at a trifling increase of the expense already incurred.

Experiment is, after all, the only true way of dealing with a subject on which there exists such a diversity of opinion, and that must be, to a certain extent, of a speculative character, from the variety and complication of circumstances by which it is surrounded.

It is therefore not only a matter of interest to science, but of the greatest importance to the country, both as regards the cost and efficiency of our navy, that a method of propulsion which offers so many advantages and is now being adopted in some thousands of tons of our new war ships of various classes, should be tested by an open and fair competition of each method, for there can be very little doubt that the efficiency of the "Fleet of the Future," no matter whether it be constructed on the broadside or turret system, will depend very materially on a simple and well-considered application of the twin-screw

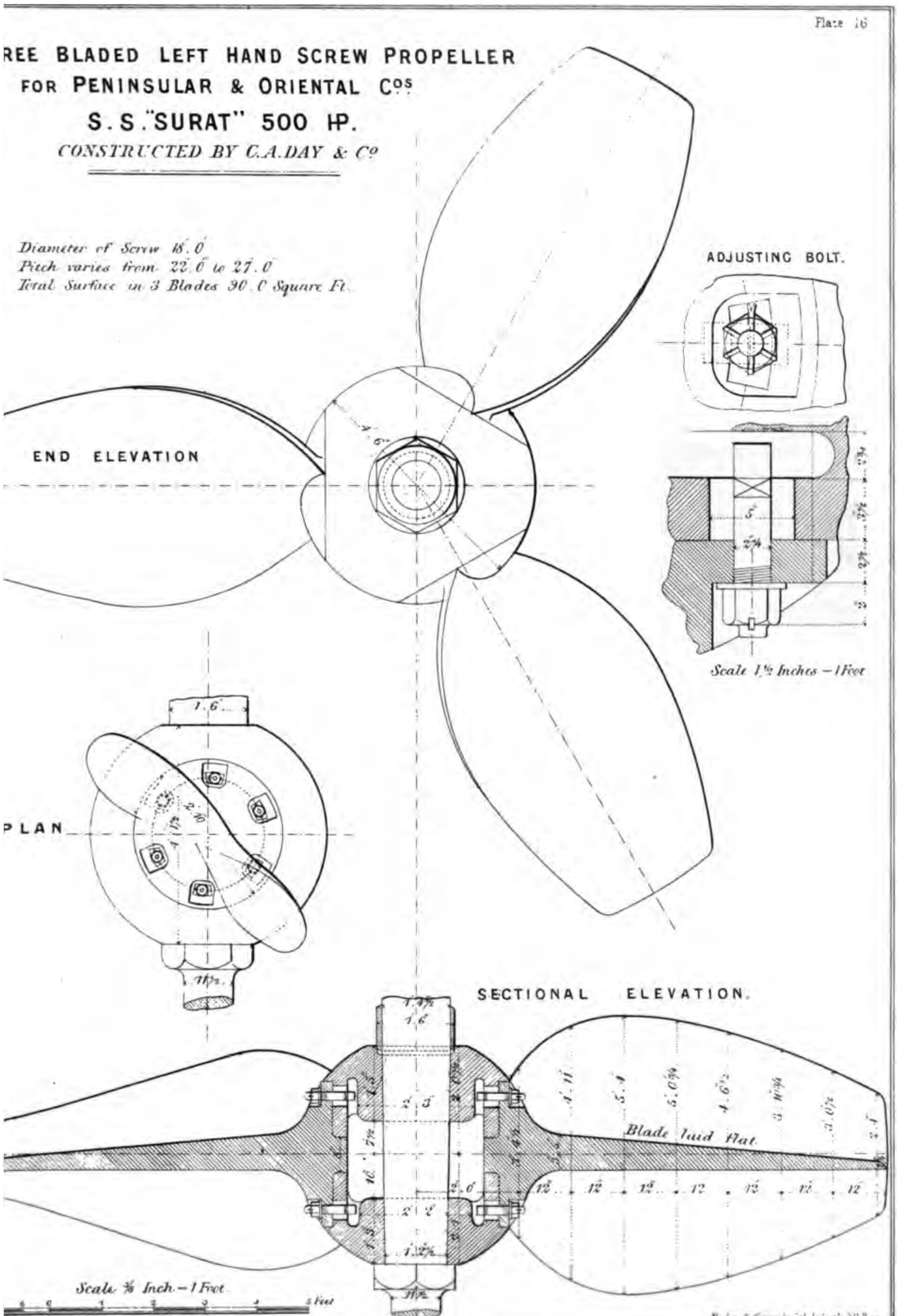
CHAPTER XI.

A DESCRIPTION OF MODERN SCREW-PROPELLERS CONSTRUCTED BY THE MOST EMINENT MARINE ENGINEERS OF ENGLAND AND SCOTLAND.

BY N. P. BURGH.

THREE-BLADED SCREW-PROPELLER FITTED TO THE PENINSULAR AND ORIENTAL COMPANY'S STEAMSHIP "SURAT," BY MESSRS. DAY AND CO. PLATE 16.—This propeller, although the common type, resembles that illustrated by Plate A, opposite to page 7, in this work, in the introductory chapter by Mr. G. B. Rennie. The relation of the two examples pertain chiefly to the forms of the flattened blades, which are very nearly similar: the difference being in the proportionate width of the blades at the boss. The width across the widest part of the blade is 2 ft. 8 in. in Plate A, and in this Plate, 16, it is exactly double, or 5 ft. 4 in.: the widths at the tips also are nearly of the same ratio: that in Plate A is 1 ft. 1 in., but in this Plate it is 2 ft. 4 in.: being a slight excess over the double proportion. The diameters of the screws partake also of the same relation: in Plate A the diameter is 8 ft. 6 in., and in Plate 16 it is 18 feet: the pitches of the former screw are from 9 ft. 6 in. to 13 ft. 6 in., while for the latter they are 22 ft. to 27 ft., so that they do not bear the same relation to each other, proportionately, as the diameters and the widths of the blades. The bosses, however, are in the same ratio as far as their diameters: that in Plate A is 2 ft. 3 in., or half of that in Plate 16, which is 4 ft. 6 in.; but the lengths bear no relation to each other of the same proportion. Of course the blade in Plate A has a lean-to forward, but this in Plate 16 inclines oppositely or aft.

The modes of securing the blades to the bosses are alike in each example: in the Plate 16 this is most clearly depicted in the sectional elevation, also in the end view and the plan; together with one bolt and nut and sections of portions of the flange and boss at an enlarged scale. The adjustment of the blade is effected by turning it on its seat in the direction for the finer or coarser pitch. Each adjusting bolt for securing the blade has

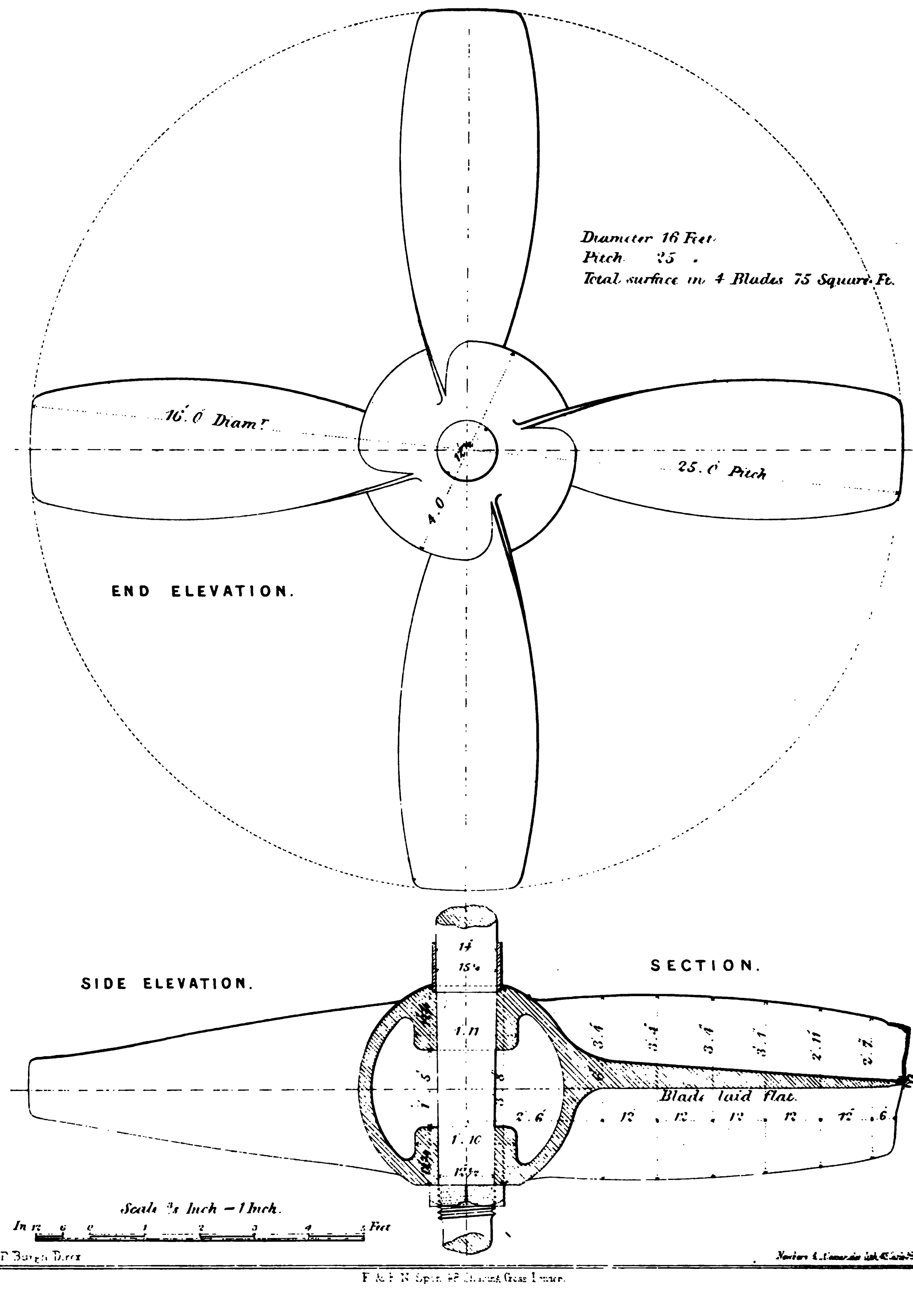


E & F N Spon, 48 Charing Cross London.

Plate 1

FOUR BLADED RIGHT HAND SCREW PROPELLER FOR HAMBURG & AMERICAN C^{os} S.S. "ALLEMANNIA" 400 HP.

CONSTRUCTED BY C.A. DAY & C^o



N.P. Burgh Direx

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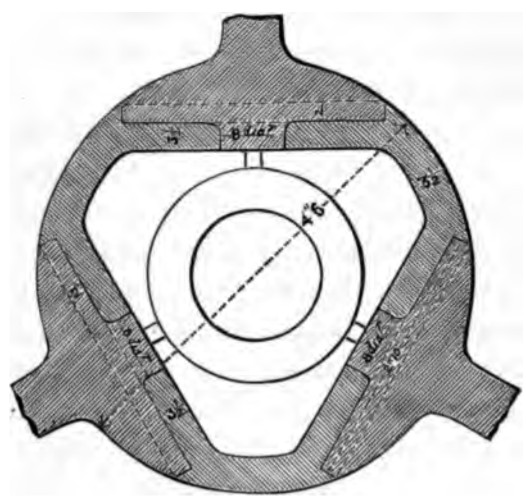
a T head which fits across the rectangular holes in the bosses through which the head passes: the bolt is then turned around and the square portion of it, directly under the head, fits into the hole as shown. The flange of the blade has elongated curved bolt holes of sufficient length to allow for the adjustment of the blade. The nuts are the ordinary kind, grooved across the top into which the split pin fits to prevent looseness; as there are six grooves the nut can be secured at six different angles.

The form of the outline of the boss and the flange connexions are globular, so that the flanges form segments, and the boss a triangular frustrum of a sphere, as shown in the end elevation: in the sectional elevation the sections of the boss and blades are clearly depicted, also the shaft and the nut for securing the boss on the shaft. As this boss is of larger dimensions than those with the preceding three-bladed propellers that we have hitherto noticed; we therefore direct attention to a sectional plan of it, illustrated by Fig. 38, which represents the connexions of the flange more clearly than in the Plate, but in this case the bolts are purposely omitted: the internal arrangement of the boss is merely that it is made as hollow as possible, compatible with sufficient thickness of metal to ensure equivalent strength. The seating for the flange is as wide as practicable, reducing thereby the diameter of the fitting projection in the centre of the flange. A comparison of the proportions of the widths of the flange seats can be arrived at by referring to the section of the boss in Plate 15, as a contrast with this under notice, as both propellers are of the same class.



Sectional Plan of the Boss of the Propeller fitted to the Steamship *Surat*, by Messrs. Day and Co. Scale ½ in. = 1 ft.

Fig. 38.

FOUR-BLADED SCREW-PROPELLER FITTED TO THE HAMBURGH AND AMERICAN COMPANY'S STEAMSHIP "ALLEMANNIA" BY MESSRS. DAY AND CO. PLATE 17.—This example is the narrow four-bladed class; the blades and the boss being cast together, therefore the advantages to be derived by the adjustment of the blades to alter their pitch are dispensed with, and give place to simplicity of construction. The boss is globular, with flattened ends; the shaft passes through it, and is secured at the aft end by a nut. In this case, as in Plate 3, the boss is hollow, in accordance with the requisite thickness of the metal for sufficient strength. This is shown by the side elevation, which depicts also the vertical section of the blade, and its length on the line of the keel, and the shape when flattened.

The shape of the blade is entirely different to any we have yet noticed, being a

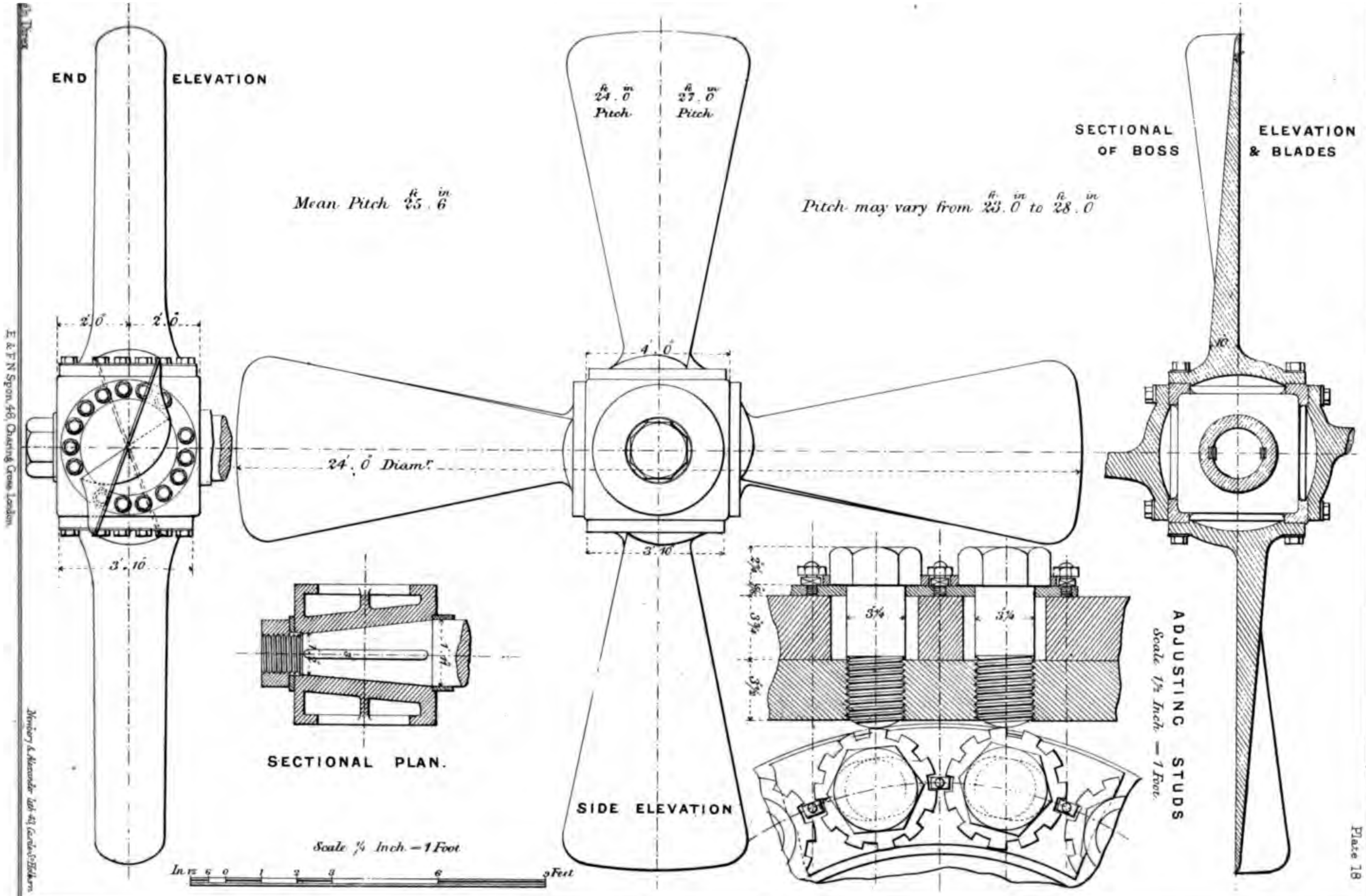
portion of the radial form combined with the outline of the curved type; so that it can be termed "semi-radial," as depicted by the end elevation. The side view of the blade is peculiar, on account of the sides being nearly straight from the boss to the tip, with scarcely any curve in the outline.

This class of propeller has produced good results, and for certain forms of hulls is particularly applicable; the objections to its general adoption are, that as the blades are cast with the boss, the fracture of one blade disables the propeller *in toto* as a complete instrument, and thus entails its entire removal, with the expense of a new propeller in its place; the non-adjustment of the blades, although admitting simple construction, loses the benefit of altering the pitch to ensure the best result as far as speed for the hull is concerned, which is of course the principal attainment.

Four-bladed Adjustable Screw-Propeller fitted to Her Majesty's Ship "Minotaur" by Messrs. John Penn and Son. Plate 18.—This plate illustrates the most modern example of four-bladed screw-propellers, which Messrs. Penn have lately constructed for some of the largest ironclad ships in the Royal Navy. The principles on which the helical form of the blades is based are those by M. Mangin; the geometry of the system is illustrated by Plate 6, and explained in page 36. It will be seen that in the present case the pitch of the leading half of the blade is 27 ft., and that following 24 ft., making a difference of 3 ft.; the transverse section, therefore, is of two angles, similarly to that illustrated in Plate 6. The blades are connected to the boss by studs, which screw into flanges especially provided for that purpose. The shape of the boss, although represented as square, is curved at the corners, thus blending the circular with the square outline. This will be readily understood by referring to the sectional elevation and the end view, the former also showing two half blades, and the latter four complete. The flanges of the blades are curved about their centres, the surrounding flat portion being for the stud plates to fit on. The number of studs used to secure each blade is depicted by the side elevation, which of course is a plan also—a geometrical question that has been explained in page 38.

The end view of the blades is perfectly radial, with their extremities curved by small radii, the side view being a parallel outline for nearly the entire length of the blade; we may add that the principle of the geometry of this form has been fully explained at the commencement of Chapter III.

The method for securing the boss on the shaft is by two horizontal, or rather longitudinal keys, directly opposite each other, and a nut beyond; this is shown by the sectional plan and the sectional elevation; the former view also depicts the nut on the extremity of the shaft in section, and its end and side views are shown by the respective elevations of the propeller. This mode of securing the boss on the shaft is a wide contrast with that shown in Plates 11 and 12, where *side* keys are adopted in preference to those longitudinally placed.



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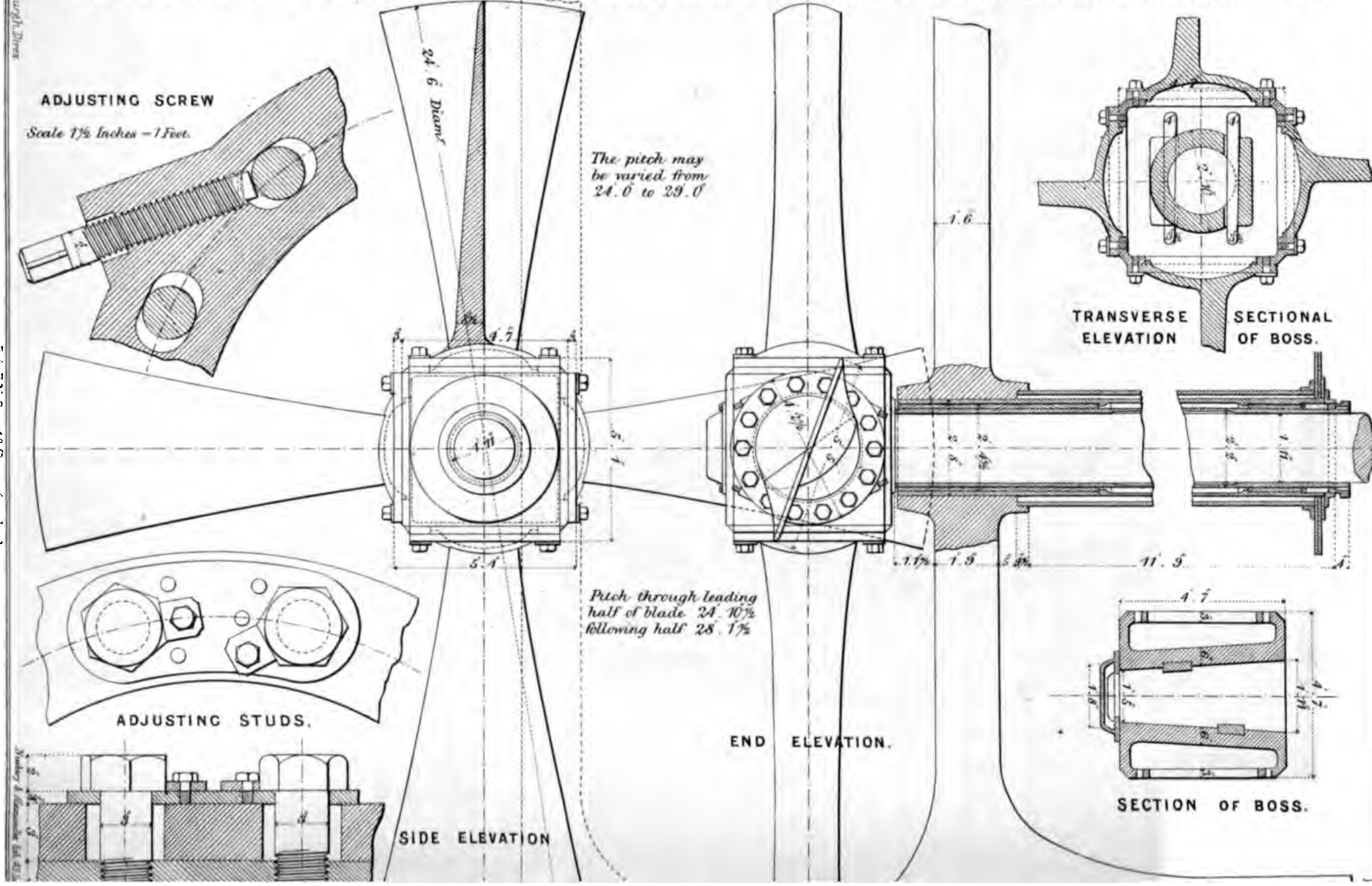
Newbery & Alexander lith 43, Castle St. Holborn

4 BLADED SCREW PROPELLER FOR H.M.S. "AGINCOURT" 1350 HP. BY MESSRS MAUDSLAY SONS & FIELD.



E. & F. N. Spon 48 Charing Cross London

The remaining feature to be noticed in this example of propeller is the adjusting studs and the method Messrs. Penn adopt to ensure their fixture, which reflects credit on the part of the designers, being as novel as it is efficacious. It will be seen in the Plate that the arrangement is shown separately from the other view at an enlarged scale: each flange stud screws into the metal appointed, and passes through the elongated holes in the flange of the blade, the heads resting on a flange plate. To prevent these studs from becoming loose or unscrewing, the heads of each are surrounded by a ring of metal of a suitable thickness: the outer edge of each ring is indented or slotted, thus forming spaces and teeth. Between the rings on the pitch line of the main studs are stop studs, having square collars, which fit into one of the spaces in each ring, and thereby lock them together; the rings are also further secured by nuts on the stop studs, holding them down on the flange plate. Then, as each main stud head is surrounded by each ring, and the latter are connected as described, each set of flange studs are combined together, so that one head cannot turn or unscrew its stud without shifting that next to it, and so on in rotation from one to the other throughout the set. It will be noticed that each ring has eleven slots or spaces on its periphery; there are, therefore, eleven separate angles to which the studs can be screwed up to for securing the flange of the blade to the boss.

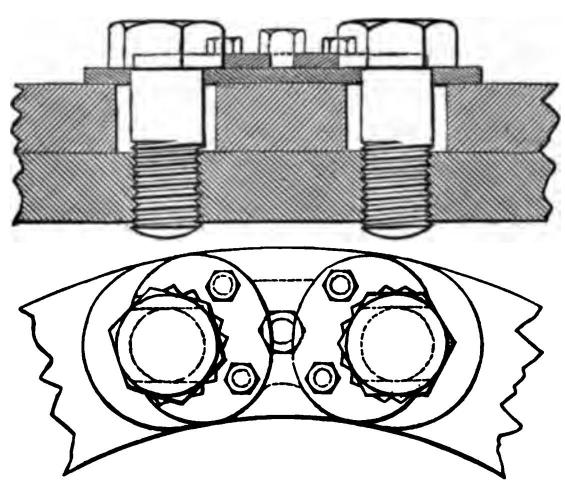
FOUR-BLADED SCREW-PROPELLER FITTED TO HER MAJESTY'S SHIP "AGINCOURT," BY MESSRS. MAUDSLAY, SONS, AND FIELD. PLATE 19.—The example of propeller illustrated by this plate is the most modern kind by the firm cited. To put forth all the particulars of it in as practical a manner as would be required for actual construction, we have illustrated complete end and side elevations, two sectional views of the boss, and, at an enlarged scale, some portion of the details.

The side elevation is a complete view of the four blades, showing the vertical ection of one blade, the studs at each side of the flanges, and the curves of the blades at heir roots, in direct connexion with the flanges, the boss, and the shaft-cap; also the ircular portion surrounding the cap, which is the limit of the curved portion of the boss o which we referred in the preceding page in allusion to that in Plate 18. The end elevaion shows the end view of one blade, which of course is its plan also; the flange with the ositions and number of the studs; the side elevations of the upper and under blades ith the corner studs, as in the side elevation; together with the limits of the boss and ne shaft-cap—it may be added in passing that an enlarged view of a similar cap by the ame maker is shown in Plate 12 at page 81. In the view under notice is shown also the tern and rudder posts; the latter and its support in dotted lines across the side elevaon; the stern post is in section in front of the boss, to depict the stern and shaft ubing in section, together with the bearing. Prolonged from this is the forward bearing or the shaft tube and the stuffing box, both in section also. Directly above this is the ransverse sectional elevation of the boss, which shows the flange connexion for the

blades, their studs, and the form of the roots between the flat portions of the flanges; centrally of this is the shaft boss and the securing keys which pass laterally of the diameter of the shaft to fix the boss as those illustrated in Plates 11 and 12. In the latter plate an enlarged view of the securing key and cap is shown, also the caps in their position, and as the keys in the Plate 19 are almost identical with those, it has been considered not essential to illustrate them again in detail.

Below the stern tubing is the sectional plan of the boss, which shows the taper for the shaft, and position of each securing key, also the cap and thrust-ring; this ring is precisely the same in design and arrangement as that illustrated in detail in Plate 12, to which subject we have already referred.

The details of the adjusting studs next come under notice; these are illustrated at the foot of the plate; the flanges are in section, also the flange and set plates; on noticing the plan of this, the form and position of the set plates can be understood; they are simply square plates secured by studs at either of the three points indicated by the stud holes and the relative angle of the main stud head, one set plate is shown securing the head at the edge of the flange plate and the other at its centre.



Messrs. Maudslay's method for securing the Flange Studs for Propeller Blades.

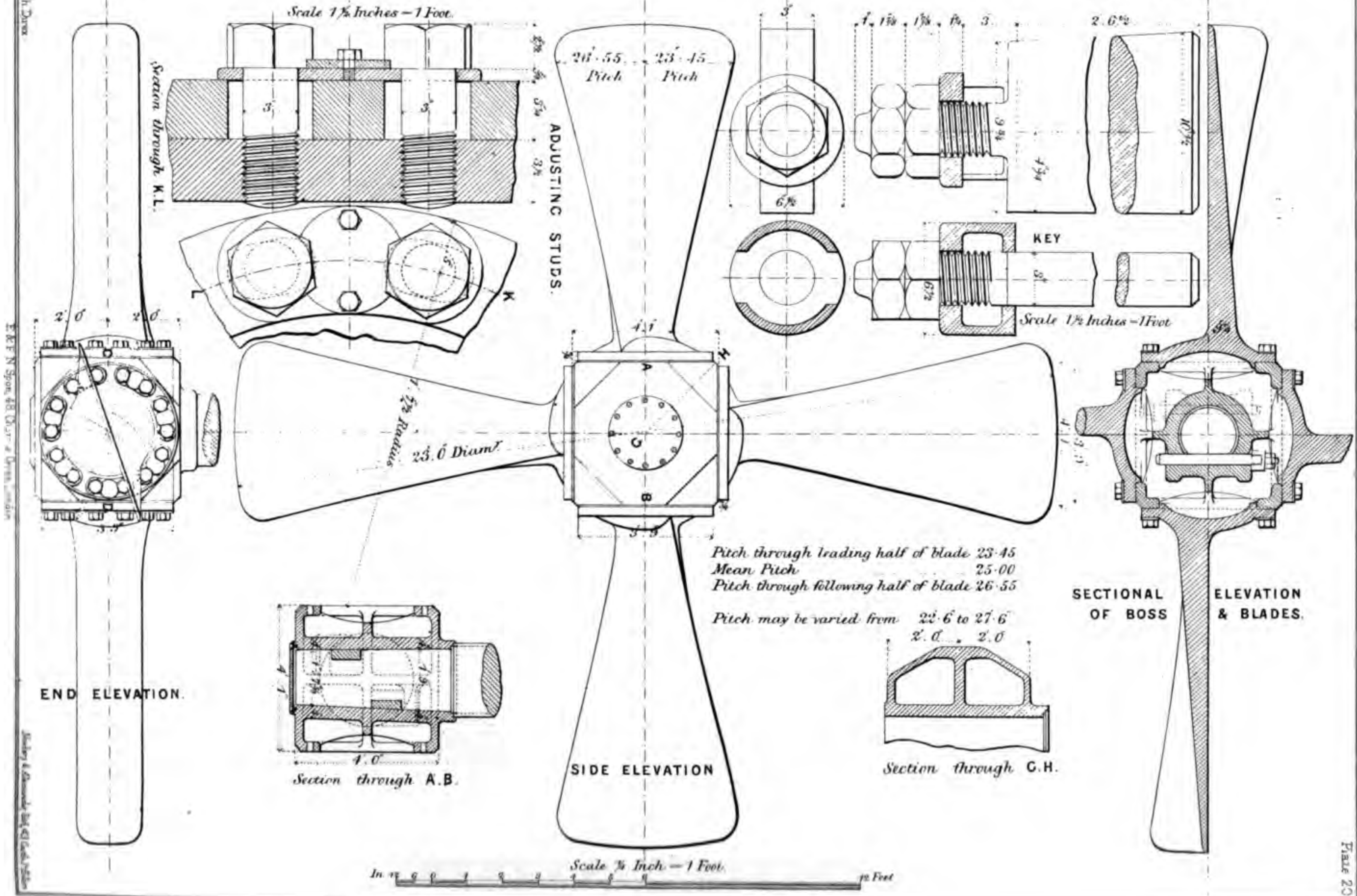
Fig. 39.

Messrs. Maudslay do not confine their ideas of this method for securing the stud heads as supreme, but in some instances adopt that as shown by Fig. 39. This illustration represents two views similar to those in the Plate 19; the method depicted by the Fig. 39, consists of a stop plate of metal of a curved form, the inside being indented angularly to fit a hexagonal stud head of proportional diameter across the flats as the radius of the curved limit of the indentations in the plate; the latter is secured to the flange plate by two studs, and is separately connected to each stud head.

The firm sometimes prefer to connect each pair of main stud heads by a single stop plate, its extremities being as the single plate, and the middle portion formed as shown by the dotted lines. A single stud for securing this plate is sometimes used, while in other instances two are preferred as requisite.

The remaining feature in the example of propeller under notice worthy of particular attention is the adjusting stud or screw, situated in detail opposite to the flange adjusting studs previously described. To concisely appreciate the use of these studs, we must refer

AN ORDINARY 4 BLADED ADJUSTABLE SCREW PROPELLER AS USED IN THE ROYAL NAVY.



N.P. Burgh Direx

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to the end elevation, and notice that fore and aft of the flange of the propeller blade shown as in plan, there are four stud heads projecting from small bosses that are cast with the flange and extend beyond its periphery, also shown in section in the detailed view; the utility of these studs is to turn the blade on the axis of its bearing when required to a suitable pitch. For example, if the forward corner of the blade nearest the stern post were required to be turned towards it, the forward and aft studs on the left and right hand sides would have to be turned to *force* against the two flange securing studs opposite them, or *screwed-up;* while those studs opposite must be turned to release their contact with the two flange studs, or *unscrewed;* and should the blade be required to be turned in an opposite direction these studs also would have to be reversed in their motion for the adjustment of the blades.

Messrs. Maudslay originated this method for turning the blade on its bearing; thus discarding the ordinary laborious means usually adopted, which is a clamp with handspikes or levers, worked by manual power in its rudest application, in the place of a mechanical arrangement which is as simple as it is effective.

Of course objections have been raised as to the general adoption of the mechanical means, one in particular is that the flange of the blade cannot be turned in the lathe, and thus the labour of fitting and surfacing are increased to that for the ordinary flange; this matter, however, is puny in its objection in comparison with the advantage that the stud arrangement has over the clamp and manual power method; indeed the difference in the two methods is so palpable to the scientific mind that the one may be termed the result of thought, and the other an application without it.

The form of the blade of this propeller is that usually preferred by Messrs. Maudslay, being the radial kind, with neither corner rounded off. The blade of the screw shown by Plate 13, at page 100, is the same shape as this, but of smaller dimensions, and serves, therefore, as an illustration that the firm have well proved this shape for blades of various sizes, which fact also proves that what is deemed to be the correct form by one firm is practically contradicted by another.

Modern four-bladed Screw-propeller, as used in the Royal Navy. Plate 20.—This example of propeller is precisely similar to that originally fitted to Her Majesty's Ship *Lord Clyde,* the present screw for which is illustrated by Plate 11, at page 79. The propeller now under notice is illustrated by two complete views, one sectional elevation, sections of the boss, and the details, at an enlarged scale, of the securing key and adjusting flange studs.

The side elevation depicts the four blades and the boss, with the shaft plate and the number of studs for securing it. The end elevation shows the end view of one blade with its flange, the securing studs and stop plates in position; above and below the boss are the two vertical blades with the studs for securing them. At the opposite end of the

plate is the sectional elevational of the boss and two blades—the remaining two being broken off to economise space.

The form of the root of the blade is similar to that shown in Plates 18 and 19; and the central portion of the boss for securing it on the shaft is nearly as that shown in the latter plate also. The form of the boss in this case is unlike either of the two others we have referred to consecutively; both of them are curved at the ends beyond the blade flanges, but this boss is angularly shaped at that part, as shown by the section through G, H. The sectional plan of the boss, which is the section through A, B, is very like that view in Plate 19, excepting the taper of the shaft; the securing keys also do not indent into the boss-line of the taper, as in the other case.

The metal surrounding the shaft is ribbed, to ensure sufficient strength of material, with two ribs transversely and four longitudinally; the former are shown in section in the boss section through A, B, and the latter in the sectional elevation; another connecting rib is shown also in the section through G, H.

Passing from the boss, we turn to the detailed section of the securing key, which is arranged very similar to that illustrated in position in Plate 11, at page 79. The mode for securing the key when it is tight is by double nuts, the lower or inner nut fits on a washer of peculiar form; its peculiarity being that, as the lower portion of the washer clasps the sides of the key, it cannot turn when the nut is turning to fix the key.

As the washer nuts and key are fully illustrated by four views, we can dispense with further description of them, and allude next to the details of the adjusting studs, and the means adopted to secure them. The illustrations of these are situated between the end and side elevations of the propeller; the flanges of the boss and blades are shown in section, also the flange and stop-plates; a plan of these details is also illustrated, so that their form and arrangement are apparent. The stud and flange plate are as those illustrated in Plate 19, but the arrangement of the "stop" plate is widely different: it is that this plate fits between each pair of stud heads, and is secured by two set studs; being, indeed, similar in its connexion as that illustrated partly in dotted lines by Fig. 39, in page 126.

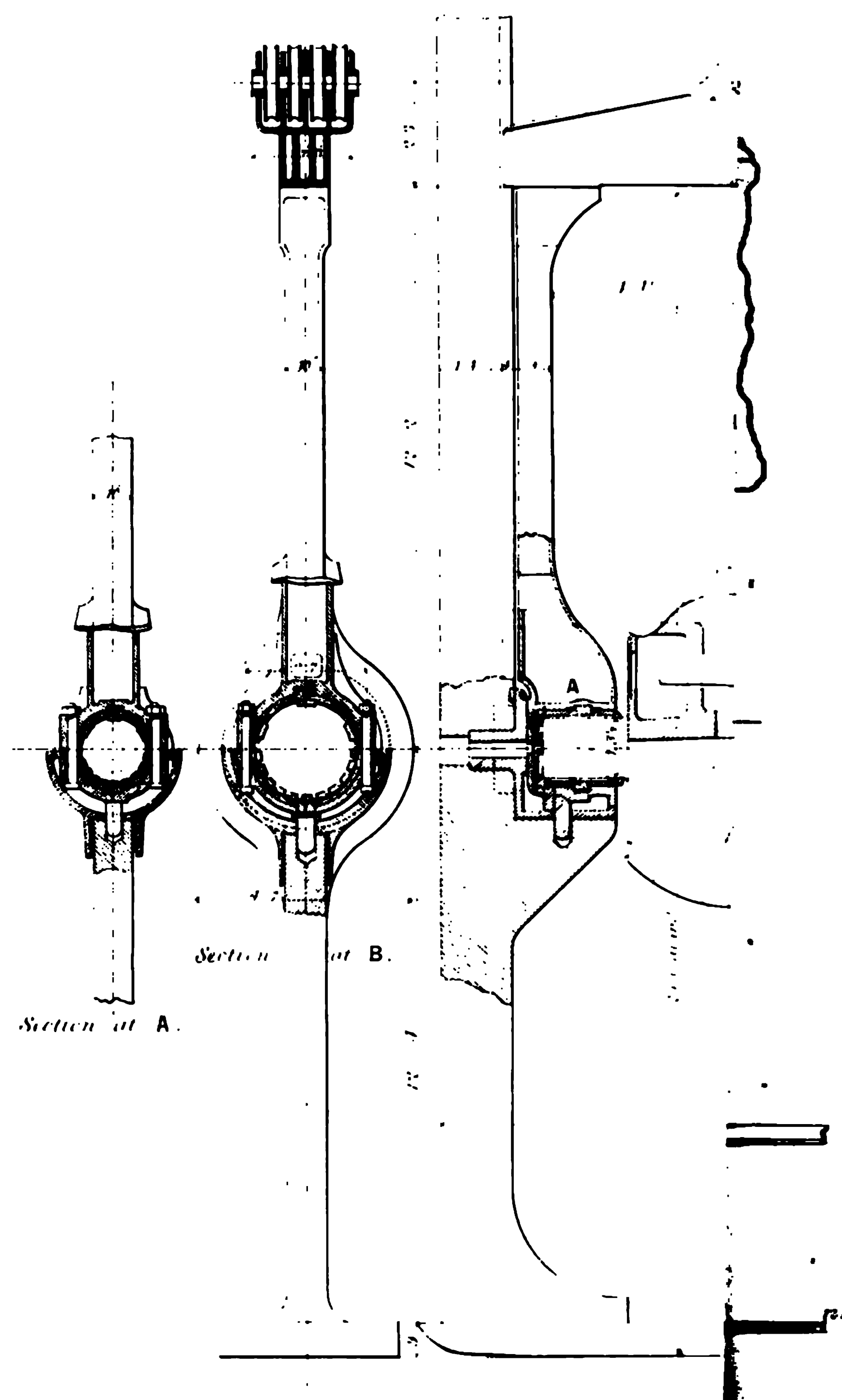
The shape of the blade of the propeller now under notice is the radial kind in elevation with the corners curved instead of angular, as those in Plates 13 and 19; the helical form of the blade is on the "Mangin" principle, which has been already fully explained and illustrated in page 76.

Having now completed the description of three examples of the most modern adjusting four-bladed screw propellers by the leading firms in England, we will next direct attention to a comparison of the main features in each.

The outlines of the blades of the propeller in Plate 18, and that in Plate 20, are very much the same, both are radial, and each have the corners curved with nearly equal radii; the form at the roots also are alike, and the flange connexions, as shown by the sectional

Plate 21

SCF



N P Burgh Delt.

& Alexander lith.

ɜ are the same; there is a vast difference, however, in the modes of securing the ı the shafts; the *Minotaur* screw boss has longitudinal keys, but the *Lord Clyde* ss has lateral keys; being, indeed, two separate methods at right angles to each The keys in the *Minotaur* screw are exposed to a continuous *elongated* shearing ut the keys in the *Lord Clyde* screw are subject to a direct cross shearing strain, . with a tensile strain; as also those for the screw of the *Agincourt*, shown by

The two modes for securing the cross keys are different; that for the *Agincourt* plates and studs, but for the *Lord Clyde* it is simply double nuts and washers.

t to be compared are the three arrangements for preventing the screw-blade ıds from unscrewing; the *Minotaur* has a toothed ring surrounding each head set stud locks two rings; the *Agincourt* has separate set plates and studs with sitions to meet the requirement; and the *Lord Clyde* has a twin end set plate each pair of stud heads, with two studs to each plate; so that the three firms, Penn, Maudslay, and Ravenhill, have obtained one acquest by three different each claiming separate advantages.

ing compared the leading features of the details of these propellers, we will next the latest results of their performances, including that of the propeller fitted to ɪsty's ship *Lord Warden.*

LE OF THE LEADING PROPORTIONS AND PERFORMANCES OF THE MOST MODERN FOUR-BLADED PROPELLERS USED IN THE ROYAL NAVY.

	Name of Ship in the Royal Navy.	Type of Propeller.	Diameter of Screw. Ft. In.	Leading Pitch of Blade. Ft. In.	Following Pitch of Blade. Ft. In.	Mean Pitch of Blade. Ft. In.	Adjustable Pitches. Ft. Ft.	Pitch set at. Ft. In.	No. of Blades.	No. of revolutions per minute	Speed of ship in knots per hour.
-	Achilles	Mangin .	24 6	28 0	25 0	26 6	24 to 29	25 5	Four.	49	13·419
-	Minotaur . . .	Mangin .	24 0	27 0	24 0	25 6	23 „ 28	25 0	Four.	55·913	14·411
-	Lord Warden .	Common .	23 0	None.	None.	25 0	22·5 „ 27·5	21 4½	Four.	63·31	13·492
-	Agincourt . . .	Mangin .	24 6	24 10½	28 1½	26 6	24 „ 29	23 3	Four.	52·6	15·433

ɪTHS' SCREW-PROPELLER AND RAISING FRAME FITTED TO HER MAJESTY'S SHIP . " BY MESSRS. JOHN PENN AND SON. PLATE 21.—The *Warrior* is well known to of our iron clad ships; equally well known also are the doubts of her success ɪrustworthy at sea, which were freely expressed before she contested with the the main line of argument against her was, that as experience was wanting mode of constructing a hull that carried such a mass and weight of metal f wrought iron four to five inches thick; her failure might be deemed more n otherwise. The *Warrior* has, however, proved to be the best sea ship of

all the armour-plated hulls that have been since constructed; for her well conducted behaviour in a sea way has proved that, although perhaps her designers were playing at a game of "hit or miss" when they designed her, they have not since followed into as successful a groove as they once entered on blindfolded.

Knowing, as we do, that the propeller and its fittings, mode of connexion with the shaft, &c., have much to do with the speed of the ship, we solicited a copy of the working drawings of those details from Messrs. Penn, which are faithfully illustrated at a reduced scale in the Plate 21. The arrangement of the blade's connexion with the boss is very similar to those shown in Plate 10, at page 77; the securing key is depicted there at right angles with the line of keel, but in the present example it is parallel with it. The form of the boss is a frustrum of a sphere and that of the blades the ordinary Griffiths' type.

Passing from the propeller we come next to the raising frame; this portion is illustrated in detail by three sectional elevations and a plan; the sections in each view relate to the bearings for the propeller, which are Messrs Penn's well proved lignum-vitæ strips, secured at intervals in a gun-metal tube. Treating first of the forward bearing, it is composed of *three* wide strips of wood above the centre line, and *eleven* strips below it; the cap and lower or supporting portion are connected horizontally on the centre line and secured by bolts and nuts, two on each side; and a guide projection ensures that on the descent of the frame the lower portion of the bearing shall sit firmly on the bracket for supporting it. Next, the aft bearing requires attention; this has also three wide strips of wood above the centre line, but only nine below it; the connexion of this cap and support is central, and two bolts and nuts secure them on each side; a guide projection is also cast on to the lower portion, as for the forward bearings. As these bearings are fully illustrated, they do not require any further description.

Ascending from the bearings in our notice, we arrive at the cross piece and its fittings. This piece is connected to the sides by bolts and nuts; a plan of them being depicted. The stop lever for the blade is shown in dotted lines, also the raising and lowering screw-rod and the catch lever with the spring at its back; of course there are two catch levers and ratchets, although one of each is only shown. The complete arrangement of the propeller and lifting frame is shown by the plan; also the form and dimensions of the well-hole through which they are raised.

Leaving this, we turn to the rudder and stern-post brackets, together with the shaft tubing and bearings. The rudder-post bracket is shown in section by two views, the one in the sectional elevation, and the other by the tranverse view which is termed the "Section at A." This bracket is recessed into the rudder-post aft of the bearing, and below it clasps the projection on each side. Of similar arrangement for the connexion also is the stern-post bracket, a section of which is shown in the sectional elevation; this post has a circular projection on it to enclose the bracket on the forward side and also to

support the portion that surrounds the tubing, and likewise as the rudder-post it has an angular projection to support the framing bearing—a transverse section of this is given in the view termed the "Section at B."

The coupling for the propeller is the "cheese" type, which is supported semicircularly on strips of lignum-vitæ fitted into channels suitably formed in the brackets; of course the T portion of the coupling is cast with the boss portion of the propeller which is of gun-metal, and equally, of course, as the shaft portion of the coupling is of wrought iron, it is encased in gun-metal to prevent oxidation on the bearing.

The stern tubing also is of gun-metal, and fitted at each end for suitable lengths with lignum-vitæ strips which surround the shaft tubing; at the forward end is the stuffing-box and gland and the adjusting studs, also the bulkhead plating of the hull.

Leading on from this is the first supporting block, which is of cast iron and secured by wrought-iron studs, bolts, and nuts; this shaft-bearing portion is lined with soft metal to reduce the friction. Beyond this block is the shaft coupling, being two discs forged on the shaft and connected together by bolts and nuts—outside of this is the second block. The supports for these blocks are frames of plating and angle iron, as shown, connected to the hull, but separate from the main structure.

Directly over the coupling and blocks is the thrust block, shown by a sectional elevation and a complete end view; the shaft bearing is circular internally and externally, thus forming a ring in halves; the block encasing it is square, and divided centrally in a line with the ring bearing, and is connected by bolts and nuts. The seating for the under portion of the block is a plate with two longitudinal vertical ribs, one on each side of the shaft, and the base is secured to the hull framing by bolts and nuts. This framing is similar to that for the other blocks; being a combination of plate and angle iron.

As the hull to which these details have been fitted has been successful, and as we have stated, much depended on their arrangement, we record their leading dimensions which are compiled from drawings put at our disposal.

PROPORTIONS OF THE BOSS.—Diameter, 6 ft. 7½ in.; length, 4 ft. 7½ in.; thickness of the ends, 2 in.; thickness of the curved portion, 1½ in.; thickness of the seating for the blade flange, 2¼ in.; thickness of the keying metal that supports the blade, 3½ in.; diameter of aft gudgeon, 1 ft. 3½ in., length, 1 ft. 9¼ in., thickness of metal, 4½ in.; diameter of forward gudgeon, 1 ft. 11½ in., length, 1 ft. 11½ in., thickness of metal, 7½ in.; diameter of coupling flange, 3 ft. 3 in., thickness, 2½ in.

PROPORTIONS OF THE BLADE.—Thickness at the root, 8 in.; thickness near the tip, 1½ in.; amount of lean-to, 11 in.; width at the tip, 3 ft.; diameter of the flange, 3 ft. 2½ in.; thickness, 2 in.; diameter of support, 1 ft. 5¾ in., length, 1 ft. 10¼ in.; mean depth of securing key, 9 in., length, 3 ft. 3½ in.

PROPORTIONS OF THE FRAMING.—Diameter of forward bearing, 1 ft. 11½ in.; widths of

lower strips of lignum-vitæ, 2½ in. (face) and 3 in. (back), thickness, ⅞ in.; widths of upper strips, 6 in. (face) and 6½ in. (back), length, 1 ft. 8 in., thickness, ⅞ in.; thickness of tube, 1½ in.; thickness of supporting portion and cap, 2 in.; diameter of securing bolts 2½ in. (4); diameter of aft bearing, 1 ft. 3½ in.; widths of lower strips of lignum-vitæ, 2 in (face), 2⅜ in. (back), thickness, ¾ in.; widths of upper strips, 4 in. (face), 4½ in. (back), length 1 ft. 6½ in., thickness, ⅞ in.; thickness of tube, 1½ in.; thickness of supporting portion and cap, 2 in., diameter of bolts, 2⅜ in. (4); diameter of guide projection, 4½ in.; thickness of the metal of fore and aft side frames, 1¼ in. and 1½ in.; length of cross piece 10 ft. 6 in.; depth at the ends, 1 ft. 3 in.; depth at the centre, from the centre of the pulley pin, 2 ft. 3 in.; diameter of pulley groove, 1 ft. 6 in., width, 3½ in.; diameter of pulley pin, 4 in.; length between head and washer, 2 ft. 3 in.; width of bearing between pulleys, 1¼ in.; width of outside bearings, 2 in.

Proportions of Rudder-post Bracket.—Radius of supporting portions, 1 ft. 6 in., thickness of metal, 2 in., length, 2 ft. 1 in.; diameter of recessed portion in the post, 10 in., length, 12 in., thickness of the metal, 2¾ in.; depth of under side flanges, 10½ in., thickness, 1½ in.

Proportions of Stern-post Bracket.—Radius of supporting portion, 1 ft. 11 in., thickness of metal, 2¼ in., length, 2 ft. 7½ in.; diameter of cheese portion, 3 ft. 7 in., thickness of the metal, 1⅜ in.; thickness of flange, 1¾ in.; diameter of the tubing portion, 2 ft. 6 in., thickness of the metal, 1¾ in., length, 1 ft. 6 in.; length of lignum-vitæ bearing, 2 ft. 6 in.

Proportions of Stern Tubing.—Diameter of aft bearing, 1 ft. 10¾ in.; length of bearing, 4 ft. 6 in.; width (face) of lignum-vitæ strips, 3¼ in., width (back), 4 in., thickness, ⅞ in.; thickness of tubing 2 in.—forward bearing, diameter, 1 ft. 10¼ in.; length, 1 ft. 3 in.; width (face) of lignum-vitæ strips 3¼, width (back), 4 in., thickness, ⅞ in.; thickness of tube 2 in.; thickness of shaft tube at bearings, 1¼ in., and at the hollow portion between the bearings ⅞ in. thick.

TABLE of the Leading Proportions and Performances of the most Modern Griffiths' Screw-Propellers, used in the Royal Navy.

Name of Firm.	Name of Ship in the Royal Navy.	Connexion of Propeller with the Shaft.	Diameter of Propeller.		No. of Blades.	Pitch of Screw set at.		No. of revolutions per minute.	Speed of Ship in knots per hour.
			Ft.	In.		Ft.	In.		
Messrs. Penn	Warrior	Lifting frame and cheese coupling.	24	0	2	30	0	53·14	14·079
Messrs. Penn	Bellerophon	Overhung, fixed on the shaft.	23	6	2	20	1	72·923	13·874
Messrs. Ravenhill . .	Lord Clyde	Overhung, fixed on the shaft.	23	0	2	23	6	64·33	13·66
Messrs. Maudslay . .	Lord Warden . . .	Overhung, fixed on the shaft.	23	0	2	23	6	Not tried.	

FITHS' SCREW-PROPELLER AND LIFTING FRAME, FITTED TO HER MAJESTY'S SHIP ," BY MESSRS. R. NAPIER AND SONS. PLATE 22.—The details illustrated in this plate refer to the lifting frame, on account of its novel arrangement and the sides and ce being of wrought-iron plating, instead of gun-metal, as is the usual practice. view to which we direct attention is the sectional elevation of both the frame screw-propeller; it shows also the "holding-down" gear and the rod and screw ng the propeller blade. The propeller is not shown in detail, as being the ordinary type, the illustration would be superfluous. The forward bearing is composed of itæ strips, fitted in the grooves formed in the tube, as shown also in the end section at A; the supporting portion is connected to the upper half, or cap, by . nuts, and the top of the cap is curved forward to clear the disc of the coupling, the vertical side portion. Next, as to the aft bearing, two views of this are so in section and half-complete outline; the tube is fitted with lignum-vitæ nd is seated similar as that for the forward bearing; the support and cap are d by bolts and nuts; but the top of the cap is curved at the forward side only, t side is in a line with the vertical connecting portion. The plans of these are shown over the stern tubing, both in sectional and complete views.

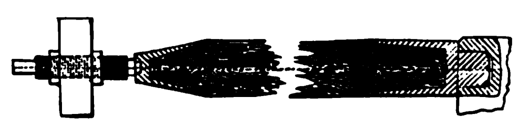
vertical sides of the framing next come under notice; these are formed of iron plating, shaped hemispherical transversely from the top of the keying tion at the cap to the connexion with the cross-piece. The connexion of the h the cap is by a key driven in at right angles with the line of the bearing of the , as shown by the end and side sectional views.

cross-piece is constructed of plating also, in the form of angle irons of unequal etted to two horizontal plates; this arrangement is shown in the side and end views, also by the plan of the frame, the latter being situated directly over the he bearings; the sides of the framing are of course rivetted to the cross-piece. now the leading particulars of the framing, we leave that for the present, and he ratchet and lever catch gear; and as a preface to the description of the ent we will first explain its purpose.

ill be remembered that at the top of the page 75 of this work, we described a chanical method for lifting the frame and the propeller there referred to, it being ore and aft vertical portions of the framing have teeth in them, and that to gear e teeth there are worms, which latter on being turned around lifted or lowered ng as required. Now there is an advantage with that arrangement, to which we ten refer, as it was unnecessary without comparison; it is that the frame cannot during the operation of lifting, for as the teeth of the worms geared into the the framing they became "stops" also as well as a means of leverage for lower- raising. Taking then that arrangement as a comparison with the ordinary

method, which being simply pulleys and ropes to lift and lower the frame and propeller, and that if it is to be entirely relied on, the safety depends on the tenacity of the ropes only, without any safeguard; it is evident that the teeth gear although slower in its action is the more safe. We must not overlook this fact either, that the two methods for raising and lowering are now specially compared, inasmuch that the one has the advantage of "stops" to prevent a sudden fall for the propeller and frame which the other has not.

It is for the reason which has just been explained as a comparison, that most all modern lifting frames are fitted with "catch" levers which fit into "ratchets" that are secured to the hull, fore and aft, of the frame, a portion of which has been shown in the Plate 21, and fully illustrated in the Plate 22 now under notice. It will be remembered also that in page 78 there is an illustration of a lifting frame and propeller shown by Fig. 23, and that there are only two catch levers shown, one at each end of the cross-piece, while it will be seen that in the present case there are four catch levers, two being at the ends of the cross-piece, and two below directly over the cap portions of the bearings. Another feature in this example also demands attention, it is that each lever is forced to its work by india-rubber springs situated over it; for as these springs act on the longer portion of the lever they press it downwards and force the inner or ratchet end into the spaces, and thus ensure a greater certainty of action than occurs with the ordinary lever, where the weight of the outer portion is relied on, to keep the inner portion to its work. Of course, in either case each lever has to be raised, or thrown out of gear, when the frame is lowering, and this is accomplished by a cord attached to the outer extremity—the hole for its connexion being shown—then on raising the lever, the frame can be readily lowered by the ropes, and should a slip or fracture occur the lever cords are loosened and each lever is directly forced into duty by the spring. Equally of course also when the frame is lifting the inner end of each lever is moving in and out of the ratchet spaces, and should a sudden release or stoppage of the upward motion of the framing occur, the springs again force the levers to their duty. Now as we have shown, the two separate positions for the levers—each in full lines when in gear, and each in dotted lines when out of gear—further description can be dispensed with; and we therefore turn to the "holding-down gear," which possesses novelty of arrangement as well as efficiency. The novelty referred to consists in the difference in the connexion of the fixing stays with the framing, and in that of the ordinary kind; the usual method being a recess or hollow space in the top of each end of the frame, into which the ends of the fixing stays fit; the upper ends being secured by set studs, as shown by the above Fig. 40; so that when the framing and propeller



Ordinary Fixing Stay for Securing the Lifting Frame of a Screw-Propeller.
Fig. 40.

require lifting, the stays are removed entirely; but in the present instance this disconnexion and removal of the stays are obviated by each being hung or supported hinge-like on the framing by pins and joints. Another advantage exceptional to the non-disconnexion alluded to is, that by this arrangement the rope pulleys are dispensed with, and when the framing requires lifting the set screws are loosened, and the upper extremities of the stays are connected together by one passing through the other, as represented in dotted lines above the cross-piece. This mode of connexion is fully apparent from the end views, where it is shown that at the section at A, the top of the stay is hollow, while that at the section at B is solid; so that the latter passes through the former; when they are in this position they are locked by a pin or set stud, and thus the frame and propeller can be lifted from under the joint of their connexion.

Leaving this matter we next attend to the frame work of the well-hole, or the passage formed in the hull through which the frame and propeller is lifted; this is shown by three views, two being in section and the third a complete plan; its structure is composed of wrought-iron plating and angle iron attached to the hull as required by rivets, studs, &c. The cover of this aperture is similarly constructed, and is formed with enclosed spaces, as shown in the side sectional elevation, through which the fixing stays pass, and the turning rod of the screw for locking the propeller blade. The entire casing, it will be seen, extends almost down to the cross-piece of the lifting frame at the forward end, and from there the outline partakes of the shape of the hull at that locality. Each of the apertures in this projecting portion is covered with a plate of metal, as shown in the three views, so that when the entire detail is in position and fastened down, the sea water is effectually prevented from entering on the deck above; which, of course, is an advantage equal to the means adopted to attain it.

With reference to the arrangement Messrs. Napier have adopted for locking the propeller blade, we may remark that as it dispenses with the lever generally used for that purpose, it lessens the amount of detail employed; their method being simply a screwed rod, fitting into a block of metal which is raised and lowered by the motion of the rod; this block slides in a support of suitable form as shown in the two sectional views, together with the sliding block.

From this portion we direct attention to the propeller coupling, which is the usual "cheese" type, the proportions of which are depicted by the side sectional elevation, and the sectional plan at B. As regards the stern and rudder-post brackets, they are of the ordinary form, and clasp the projections on the posts similarly as those in Plate 21, shown by the end views in both cases.

The stern tubing next comes under notice; this, as the other details, is novel also; the shaft tubing for the lengths of the fore and aft bearings is grooved for the reception of the strips of lignum-vitæ, as shown by the transverse view also; whereas in the general way

the stern tubing receives them, and the shaft tubing is smooth; the stuffing-box and gland are much as the usual practice, and the shapes of the flanges of both can be seen from the end view beyond the tubing.

PROPELLER AND LIFTING FRAME FOR HER MAJESTY'S GUNBOATS OF FIFTY HORSE POWER NOMINAL, FITTED BY MESSRS. JAMES WATT AND CO. PLATES 23 AND 24.—The diameter and weight of the propeller in all cases defines the arrangement and form of the lifting frame, and it is for this reason that, having illustrated and described two examples of the largest size, we for the purpose of comparison next notice an example of much less dimensions and weight. The drawings that have been put at our disposal for this purpose are illustrated by the Plates 23 and 24.

The Plate 23 contains a complete elevation of the propeller, lifting frame, stern, and rudder-posts, with an end elevation of the propeller; a complete plan, showing also the form of the aperture on the deck; a sectional plan of the boss portion of the propeller and coupling; and a top view of the frame. The companion Plate, 24, shows a sectional elevation of the entire detail, with the stern and shaft tubing, end views of the stern and rudder-post bearings, and the astern pushing plate. The arrangement of the bearings is lignum-vitæ strips and tubes as for the larger size; the supporting and upper portions are connected by bolts and nuts, as shown by the end and side views. The cross-piece is connected to the caps by rods secured by nuts at the upper ends, and by keys at the lower. The stop lever for locking the blade vertically is raised and lowered by a screw similar to that shown in Fig. 23, in page 78. The loop at the centre of the length of the cross-piece is the portion to which the rope is secured, for raising and lowering the frame and propeller. As the weight of the entire detail is light comparatively, the catch levers and ratchet pieces are dispensed with; it will be noticed, also, that there are no stern or rudder brackets; and that the aft bearing support clasps the projection on which it rests; while the forward bearing is seated within the sides of the projection; this is more apparent from the complete elevation than the sectional view, where the mode of supporting the bearings is clearly depicted, also the guide lugs on the caps and cross-piece for guiding the framing during its ascent and descent; these lugs are shown also in the plans of the propeller and cross-piece, together with the rudder and stern-posts.

This propeller is the common or radial kind, as shown by the complete view of it; the sectional view shows that the blades are adjustable, and secured to the boss by bolts and nuts, their number being shown in the complete plan. The form of the boss is globular, and the flanges of the blades are shaped accordingly, to complete the globe as far as practicable; the vertical section of the blade inclines aft with the curved side forward. The proportions of the metal of the boss and the hand holes, with their covers, for putting the flange securing bolts in position, are illustrated by the sectional plan; also the vertical rib; shown also in the sectional elevation.

PROPELLER AND LIFTING FRAME FOR: H.M. GUNBOATS OF 50 H.P. BY MESSRS. JAS. WATT & Co.

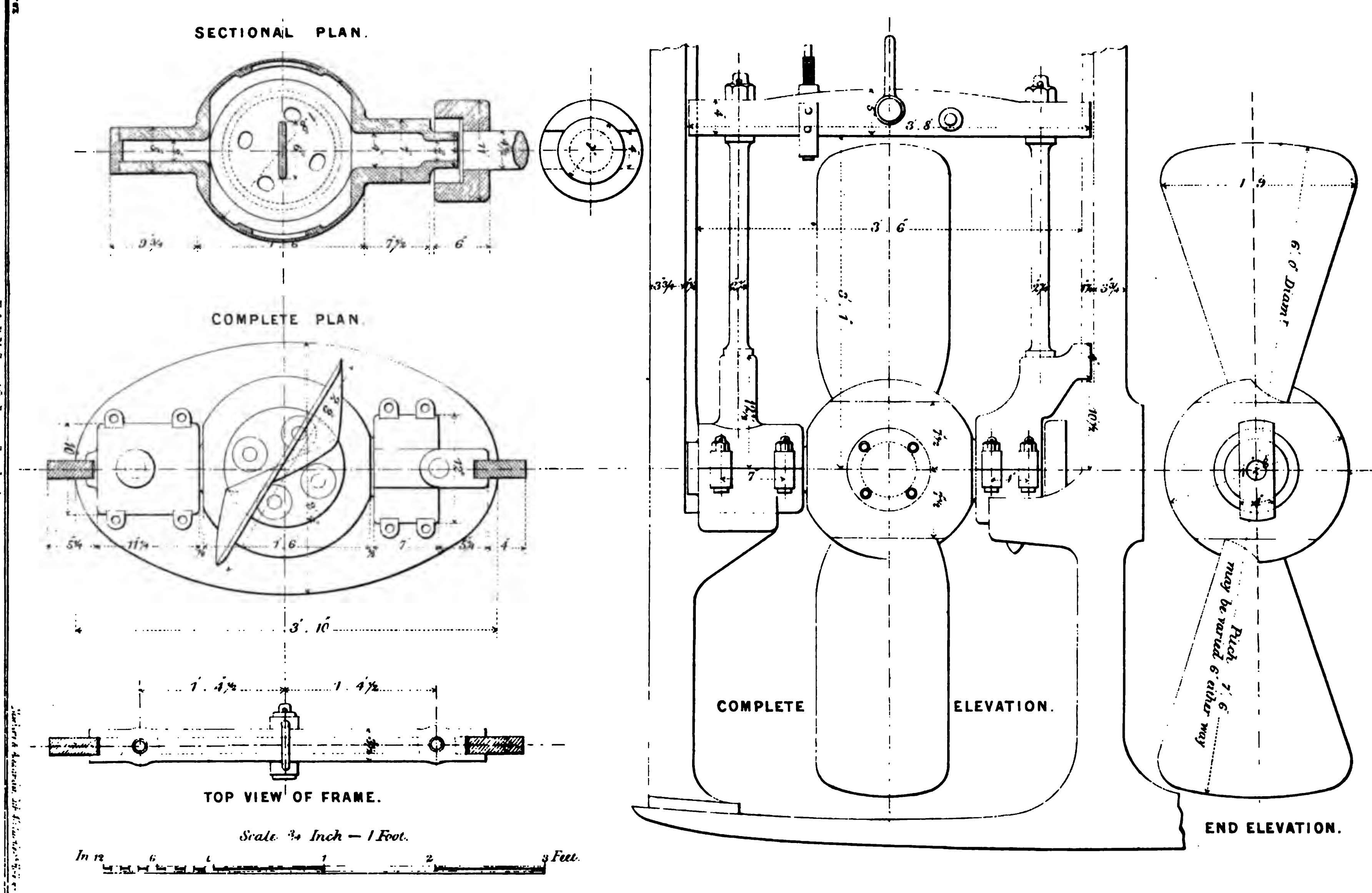


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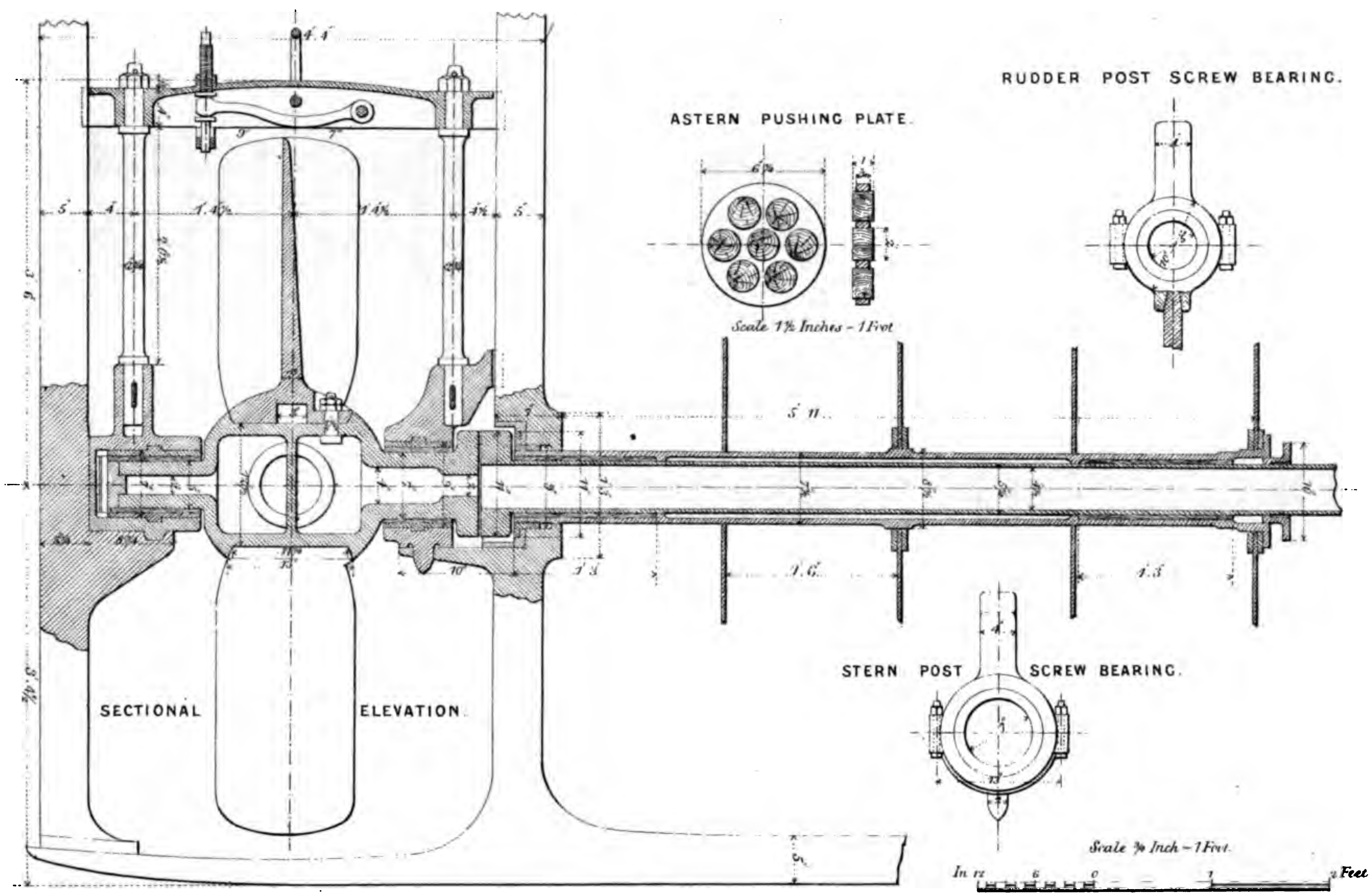
Plate 24.

PROPELLER AND LIFTING FRAME FOR H.M. GUNBOATS OF 50 H.P. BY MESSRS JAS WATT & Co



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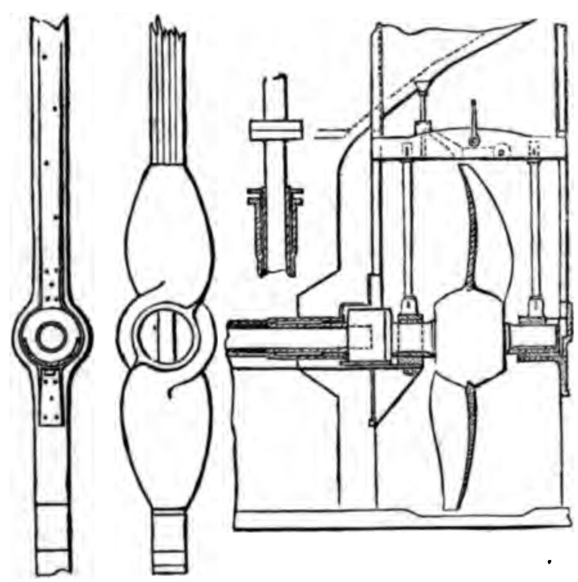
The thrust of the propeller when pushing astern is received by the astern pushing plate, which is composed of a disc of gun-metal and circular blocks of lignum-vitæ inserted through it as illustrated in detail.

The connexion of the propeller with the shaft is by the driving coupling; this is shown by the sections in elevation and plan, with an end view; the projection on the propeller gudgeon being shown also in the end elevation.

The tubing next comes under notice; this has the ordinary kind of bearings and tubes, with the usual stuffing-box and gland; the stern plates of the hull are illustrated, and the bulkhead to which the tubing is secured, so that the mode of supporting it is clearly depicted.

Of course it has been remembered that the nominal horse-power of the engines for this propeller is very small, and equally obvious that the size of the propeller is in proportion: it sometimes occurs, however, that the type of framing here adopted is applicable for propellers of at least three times the power of the one now described, and as a proof of this we illustrate an example by Fig. 41.



Propeller and Lifting Frame fitted to Her Majesty's Ships—Engined 150 Horse-power nominal collectively.
Fig. 41.

This lifting frame and details, are nearly similar to that illustrated by the Plates 23 and 24, but the propeller is the Griffiths' type, with adjustable blades: the connexion of the blade with the boss is the same as that depicted by Fig. 25, in page 80, being the key and double wedge arrangement.

As we have compared the two lifting frames in outline and detail, it will be equally fair, as a comparison, to relate the dimensions of the larger example, and particularly so as we have in the Plates 23 and 24 fully figured the details there illustrated.

Proportions of the Lifting Frame and Griffiths' Screw-propeller fitted to Her Majesty's Ships—Engined 150 Horse-power nominal collectively. Fig. 41.—Diameter of screw, 10 ft.; pitches varying from 13 ft. to 15 ft.; width of tip of blade, 1 ft. 6 in., extreme width, 3 ft. 4 in., thickness of blade at the root, $3\frac{1}{4}$ in., thickness at the tip, $\frac{5}{8}$ in.; lean-to, 5 in.; diameter of flange, 1 ft. $4\frac{3}{8}$ in.; diameter of keying projection, $8\frac{1}{4}$ in., length $9\frac{1}{4}$ in.; width of key, $4\frac{1}{2}$ in., thickness, $\frac{3}{4}$ in., length, 1 ft. 2 in. Diameter of boss, 2 ft. 9 in., length, 2 ft.; diameter of aft bearing, $8\frac{1}{4}$ in., length, 1 ft. 2 in.; diameter of forward bearing, $11\frac{1}{4}$ in., length, 1 ft. 2 in. Diameter of cross piece-supporting rods,

$2\frac{1}{4}$ in., length, 3 ft. $11\frac{1}{2}$ in.; length of cross-piece, 5 ft. $7\frac{3}{4}$ in.; length of fixing stays, 5 ft. 9 in.; diameter of driving coupling, 1 ft. $5\frac{1}{8}$ in.; thickness of disc, 2 in.; length of projection, $4\frac{1}{2}$ in., thickness, 7 in. Diameter of screw shaft, $7\frac{9}{16}$ in.; diameter of tube-bearing aft, $9\frac{1}{2}$ in., length, 2 ft. 1 in.; diameter of tube-bearing forward, $9\frac{1}{4}$ in., length, 1 ft. 3 in.; length of stern tubing, 12 ft. 8 in., diameter, $11\frac{1}{8}$ in.

Propeller and Lifting Frame fitted to Her Majesty's Steam Troop-ship "Orontes," by Messrs. James Watt and Co.—This screw-propeller and the lifting frame are examples equally worthy of notice and record as any we have already described and illustrated; and in order to put forth all the main features in the arrangement, we have given a reduced scale drawing of them from the original; so that the illustrations we are now directing attention to are copies of what were made and used for the actual construction of the entire detail.

The propeller is the Griffiths' type, with the blades adjusted by wedges and secured by keys transversely; these details are completely shown in the sectional plan and transverse section of the boss, also in the sectional elevation of the entire arrangement.

The outline of the boss is a frustrum of a sphere, and the gudgeons are cast with it; there is a peculiarity with the bearing of the aft gudgeon which is worthy of notice; it is that the actual bearing surface portion is a casing on the gudgeon, secured by a flange and six $\frac{3}{4}$ in. studs to the end of the boss as depicted; the advantage with this is, that when the bearing surface is worn it can be replaced by a new tube or casing on the gudgeon. The forward gudgeon is the usual kind, being cast with the propeller entire.

The bearings are the ordinary strips of lignum-vitæ inserted in gun-metal tubes, which are supported in the framing bearings; their caps and supports being connected by bolts and nuts, as shown by the complete views.

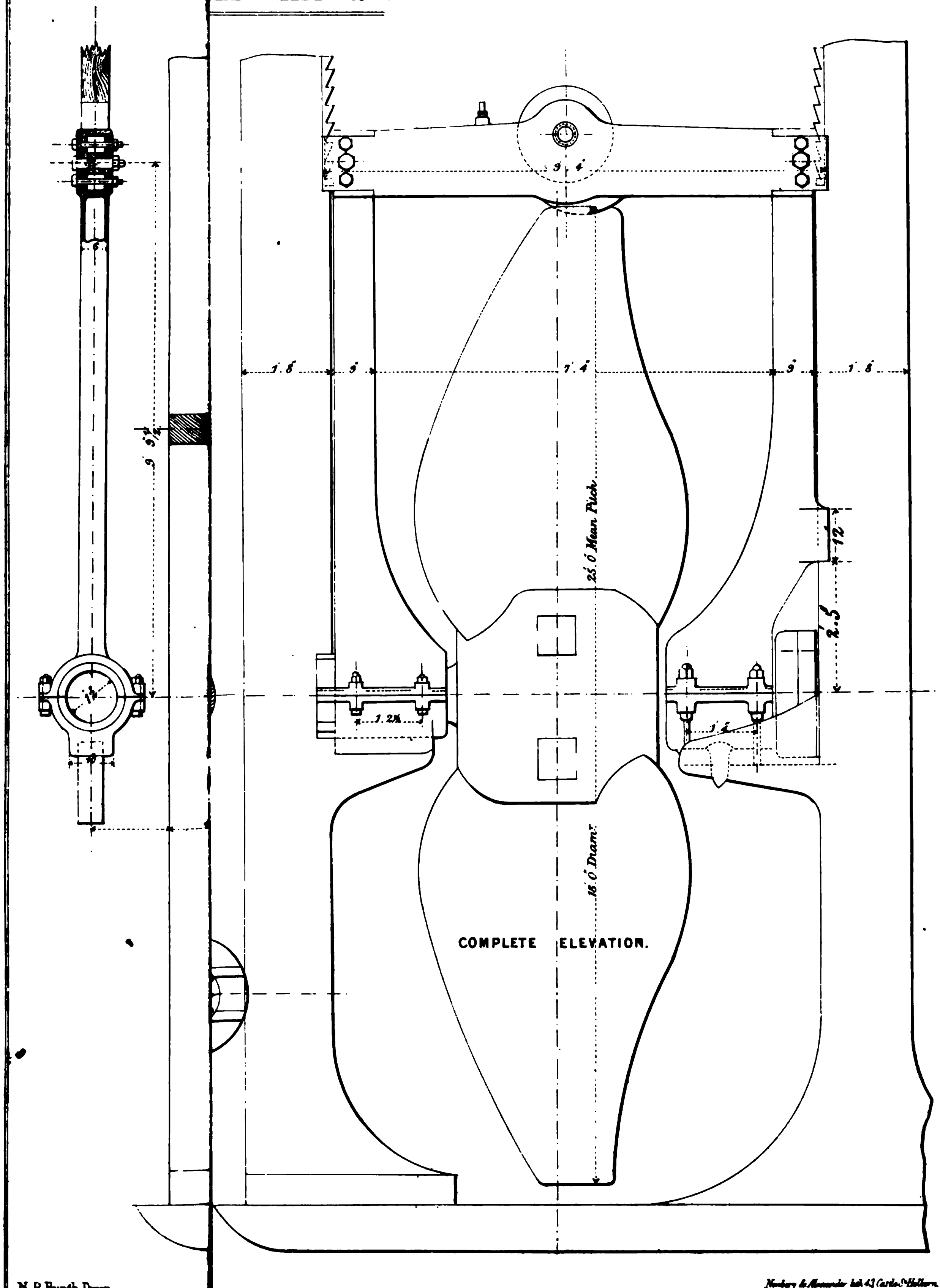
The form of the sides of the framing is novel, as depicted, not only by the sectional elevation, but also by the sectional plans over the boss and bearings, which show also the outline of the latter and the position of the connecting bolts and nuts.

Above this is the sectional view of the cross-piece, and on the left hand is the transverse sectional view of it, which clearly represents the mode adopted to connect the sides; being recesses formed in them to receive the ends of the cross-piece, and then both are secured by bolts and nuts. The catch levers, ratchet pieces, and the screw-blade stop-lever are all shown in position; and on the right hand from this is depicted the section of the cross-piece at the centre of its length, which view includes the rope pulleys and their bearings, also the pin. Directly over the catch levers are the lower ends of the fixing stays, shown in sectional and complete views, and above them is the plan of the cross-piece and its fittings with a portion in section.

The astern pushing plate next comes in the way of notice; this detail is the same kind as that illustrated in Plate 24; there are thirty-seven solid cylinders of wood in this

OR H.M.S. TROOP SHIP "ORONTES".

IES WATT & Co



N P. Burgh Direx

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se, but only seven in that, and the diameter of each piece of wood is smaller in this ample than in the former.

Passing from this, the complete plan requires attention; this view shows the blade t at the coarsest pitch; also the outline of the boss, with the key-hole covers in position; low this view is the sectional plan of the boss, which includes also the outline of the dgeons and the driving coupling. There is a peculiarity with this coupling; which is nilar also in the plan shown by the Plate 23; both examples being by the same firm; is that there is no disc on the gudgeon, but simply a projection of the usual form direct to the bearing portion; of course the shaft disc is the same as ordinary, excepting at the hollow for the projection is of two separate widths instead of one continuous mension as is the general practice.

Situated at the right hand of the plate, is the complete elevation of the propeller d framing; here, it will be noticed, is a second novelty, which the firm is to be comended for, it being that the usual stern and rudder-post brackets are dispensed with, omission shown also in a similar view in Plate 23. The aft-bearing supporting portion sps the projection on the rudder post, while that forward is recessed into the stern-post ojection; so that although the brackets in question are not introduced, suitable and uivalent supports are provided for the purpose.

On comparing the present example with that in Plate 21, the omission alluded to will strikingly conspicuous.

It next becomes worthy of notice which of the two firms is in the right way of oceeding; for if the brackets are really requisite, to omit them must be a fault of no tle consequence; but, to rest certain about this matter, we must first recognise what the ackets are for. They are introduced to form seats or supports for the under side of e bearing support of the framing, being, indeed, a connexion with the stern and ruddersts. Now, if we examine the view termed the "Section at A," in the Plate 21, and mpare it with the similar view in Plate 25, we shall see at once that although the acket is dispensed with in the latter example, the forms of the rudder-posts are ecisely alike, and that their modes for retaining the position of the portion supported are e same also; it would seem, therefore, that the aft bracket in Plate 21 might have been iitted, without doubt, if the arrangement in Plate 25 has answered; and as the latter is e older example, dispute on the point is useless.

We turn next to the forward or stern-post in the Plate 25; here again the bracket, we stated before, is left out, and its purpose represented by a suitable projection rmed on the post; comparing this method with that in Plate 21, we conclude that ere is no real advantage at all in the stern bracket when the post is formed to render omission practicable.

The matter *in toto* is really but a question of how the framing shall be supported, *i.e.*,

shall there be brackets secured to the posts for that purpose, or shall the posts have projections formed on them instead? As forging in the present day is no difficult task, we advise the formation of the projection on the posts, and the entire absence of the brackets, as preferred and carried out by Messrs. Watt on small and large scales.

The stern and shaft tubing illustrated in the Plate 25 are the usual kind, the fore and aft bearings being formed of strips of lignum-vitæ; a transverse section of the tube and strips is shown, depicting also that the stern tube has longitudinal ribs on it, as well as strengthening rings at the positions for supporting the tube.

The proportions of the details compare well with those we have illustrated before, by other firms, and the astern pushing plate is an advantage worthy of general application, as well as the absence of the stern and rudder brackets; there is indeed an air of carefulness in the entire design and arrangement, which is worthy of appreciation, without any superficial compliment, but taken solely as an example of good practice.

CHAPTER XII.

A DESCRIPTION OF THE MODERN DETAILS IN CONNEXION WITH SCREW-PROPELLERS, AS CONSTRUCTED BY THE MOST EMINENT MARINE ENGINEERS OF ENGLAND AND SCOTLAND.

By N. P. Burgh.

INTRODUCTION.—Starting with the axiom that the efficiency of any instrument depends a great deal on the application, we pave the way for the conclusion that the duty of a screw-propeller chiefly depends on the details with which it is directly connected; and as a means of acquiring knowledge of this matter, we will analyse it and arrange the main features for that purpose.

Beginning, then, with the form of the boss of the screw-propeller, let us consider what that portion has to contend with, as well as the duty it should perform. The boss, as it revolves when immersed, meets with the intermediate or central currents caused by the motion of the ship's progress, and according to Mr. Griffiths' experiments it should be globular, which he has explained in page 40 of this work, where he sums up by stating "that the best proportion for a screw-propeller is to fill up its centre with a sphere equal to *one*-third of the screw's diameter." Now, with all proper deference to that gentleman's opinions on this matter, we cannot reconcile our views to agree with his, inasmuch as the form of the boss can be *any* shape to suit the number of the blades and the mode for securing them; for when the propeller is revolving in the water, that portion of the element that surrounds the boss is whirled outward, forward, and backward by the roots of the blades, as their angles at the boss are much more acute than at the tips; the boss then moves in almost a vacant space, consequently its resistance is reduced, and therefore its form cannot affect the motion. Now, if the blades did not throw off the water, but allowed it to grasp the boss, then the globular shape perhaps is the best; but as the circumstances of the case are as we have explained, the boss can be shaped to suit the mechanical questions only.

So far, indeed, is this certain, that with all modern two, three, and four-bladed propellers the boss is square or circular, with flat ends, which are fully illustrated in this work.

Having discussed the main features of the boss, we will apply our remarks next to the bearings for supporting the propeller. Of course there can be but one answer to this question, and that is, that the lignum-vitæ strips are the best means yet known for the purpose; and the reason is, that the wood, being a bad conductor of heat, and the water in the channels between the strips of the wood acting as a lubricant, the friction of the working surfaces in contact is thereby reduced to the lowest ebb, and maintained at that level. The nearest approach to this acquisition by any other means, is by grooving the shaft or the bearing, as shown by Fig. 32, in page 106.

Next we treat of the arrangement of the bearings—two or three years ago it was deemed requisite that if a propeller weighed more than five tons it *must* be supported fore and aft; we have however lately ignored that idea, and with credit let it be said fear not to overhang a propeller weighing *twenty*-five tons, and maintain its true position by a suitable forward bearing; of course this bearing is longer than the double bearings, but the friction is not greater nor the repair more often requisite than before. The propeller fitted to Her Majesty's Ship *Agincourt*, illustrated by Plate 19, at page 125, is a good example of the late practice; as it weighs 23 tons, and is overhung; also other equally good illustrations are shown by the Plates 16, 17, 18 and 20.

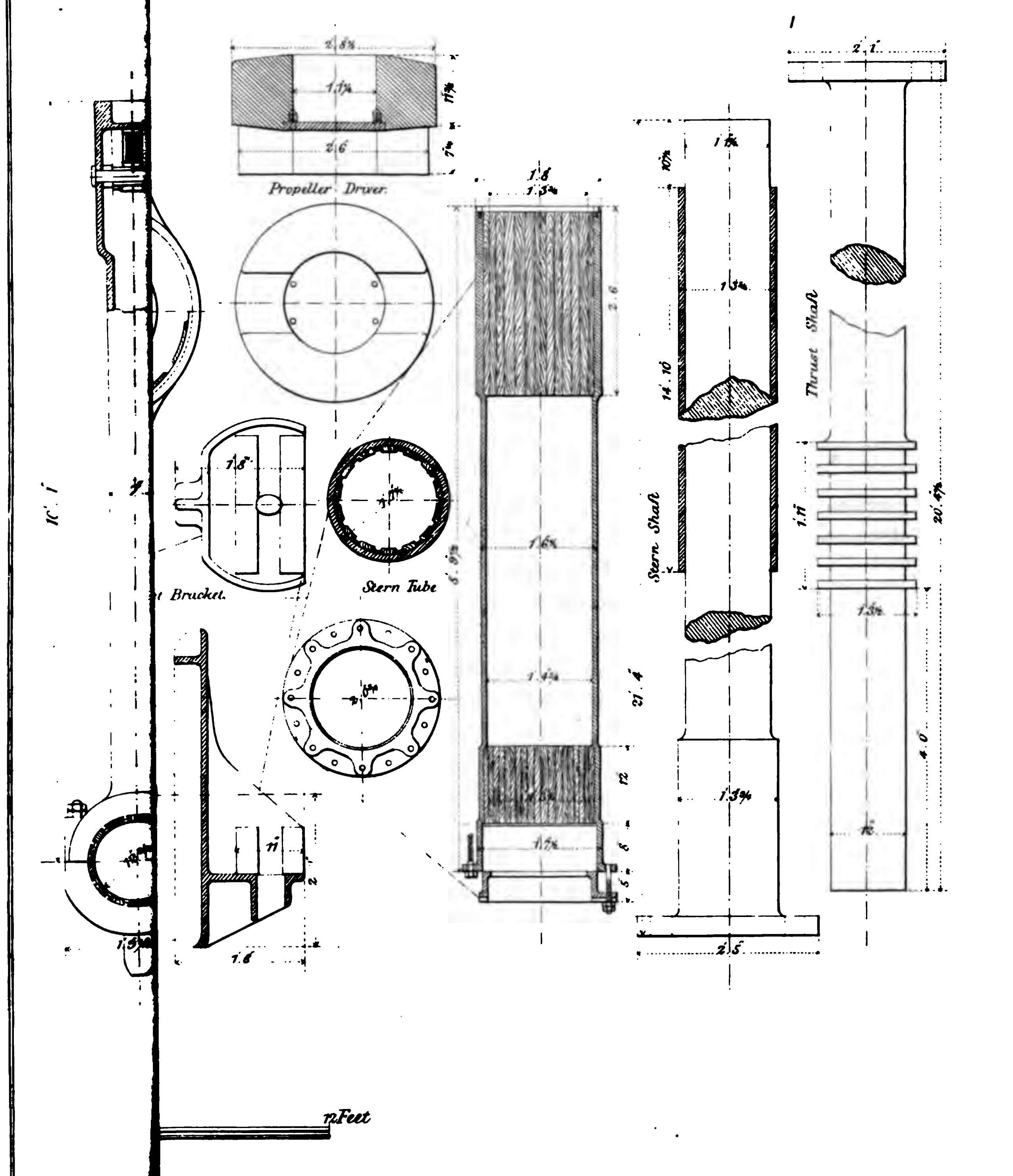
Regarding next the bearing at the stuffing-box end of the tube; it is similar to that at the stern end, and the stuffing-box and gland should be as small as practice decides.

The leading features of the details in direct connexion with the working of propellers having been explained, we now describe the most modern practice of the engineers whose experience can be fully relied on, as being the highest stage of perfection yet attained.

Details for Screw-propulsion by Messrs. Ravenhill and Hodgson. Plate 26.—The details, illustrated, to which we now direct attention are constructed by the firm mentioned as a record of their general practice; the propeller is purposely omitted, as the example that they construct is the ordinary Griffiths' type; which having been already fully explained in this work needs no repetition in the present case.

Lifting Frame.—The entire arrangement of this portion of the details is illustrated by eight views; the fore and aft gudgeon bearings are formed of lignum-vitæ strips fitted in gun-metal tubes in the usual manner; the supports and caps are connected by bolts and nuts; and the shape of the complete outline is shown by the side elevations and plans between the sections, also by the end views on each side of them. The cross-pieces, sides, and caps, are of one casting, and the cross sections of the sides are shown with the plans of the cap portions. The stop lever and raising-rod are the usual kind, also the rope pulleys and their connecting pin. The catch levers and ratchets are shaped as those we have already illustrated in Plate 25, and in both cases india-rubber loops are

AND HODGSON.



N.P Burgh. Direx

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used as springs to keep the levers in the notches of the ratchets. There is a little difference however in the two modes for supporting the levers; that in Plate 25 is by pins, but in this case it is by bosses only, and guide-stops below. The plan of the cross-piece, and its details is shown below the elevation, so that the arrangement of them is completely depicted by the two views.

One feature in the framing remains to be noticed comparatively; it is that the Messrs. Ravenhill prefer to make the lignum-vitæ strips of equal size and number for the upper and under halves of the bearings; while Messrs. Penn—the originators of the application of the strips—reduce the area of the upper surfaces of the wood considerably in proportion to the lower, as we illustrated by Plate 21. There is just cause too for this inequality of the surfaces, as the weight of the propeller and framing is on the lower half of the bearing, but the top half, only receives the friction of contact without the weight.

Stern-Post Bracket.—This detail is secured to the aft side of the stern-post, and supports the forward portions of the framing and propeller; it is made of gun-metal in one casting, and fitted with lignum-vitæ strips, which are let into a recess formed to receive them and retained by stop-plates that are secured by studs; these strips are on the lower half of the circle of the bearing only, as the upper surface has little or no frictional contact with the coupling disc; the bracket is shown in sectional and end elevations and a complete plan, therefore its entire shape can be readily understood. This arrangement presents no novelty for comment, as it is the usual practice by other firms of equal note.

Rudder-Post Bracket.—As a companion to the former detail this bracket next comes under notice; it is bolted to the forward side of the rudder-post and supports the aft portion of the framing and propeller. The complete outline is rather more simple than that previously noticed; the strips of wood too are omitted, as the bearing surface has no working contact like the other. This detail is also illustrated by three views, therefore its arrangement is equally apparent.

While we have these brackets under notice we may as well allude to the gain by their absence "by the way." When the rudder and stern-posts are of wrought iron—which they generally are now—there can be no practical advantage in having brackets to support the framing of the propeller; for after all, the projections formed on the posts support the entire details, and the brackets are but intermediate portions between the matter supported and supporting; obviously then, where is the gain in having projections formed on the posts as supports, and introducing on them a second support on which the framing rests? It occurs to us therefore that this question has been an oversight which will in due time be looked into, and we shall see that for the future "stern and rudder-post brackets" for supporting the framing of screw-propellers will be "things of the past."

Propeller Driver or Cheese Coupling.—This is shown at the side of the end elevation of the stern-post bracket, and is simply a disc of metal with a hollow or groove

at one side, and a hole in the centre; its use, from the first name, is of course evident, and we only introduce the second appellation because it is technical. The meaning of the word "cheese" in the present instance is to convey to the mind of the observer that the "driver" is shaped as a flat cheese of Gloucestershire renown, and thus the form is supposed to be readily understood; this anomaly is akin to that of the title given some years back to the "lifting frame" for the screw-propeller, which was then termed the "banjo" frame; but this is as absurd as the other mistake, for there is only one portion of both of the details that even indirectly resembles the form of the subjects they are named after; for example, the cheese and the driver are both circular in one view, and there the relation of their outline ends; the musical instrument, the banjo, is nearly circular at the larger extremity, as seen from the front or back; the end view of the lifting frame at the forward bearing nearly resembles the outline of the banjo—but not quite—and here this presumed analogy terminates; so this proves that it is most ridiculous to name engineering details after cheeses and banjos; as the terms lifting frame and driver or driving coupling are appropriate and sensible, and therefore are *really* technical from correct sonrces.

The driver is secured on the shaft by keys, and a circular plate is secured in the hollow, as shown by the sectional and end views.

Stern Tube.—This is a tube of gun-metal fitted at one end for some length with strips of lignum-vitæ. The transverse section of this part is situated directly below the end views of the driver, and shows that the strips are dovetailed into grooves suitably shaped. At the extremity of the tube a ring is secured within its periphery to prevent the strips from shifting. Opposite to this is the stuffing-box and gland, and their end view is shown below the transverse section of the tube. One of the studs for securing the tube to the bulkhead is shown, also one of the gland studs, and the number of each is shown in the end view. At the bottom of the stuffing-box another set of wood strips are dovetailed into grooves, but shorter than those at the other end of the tube.

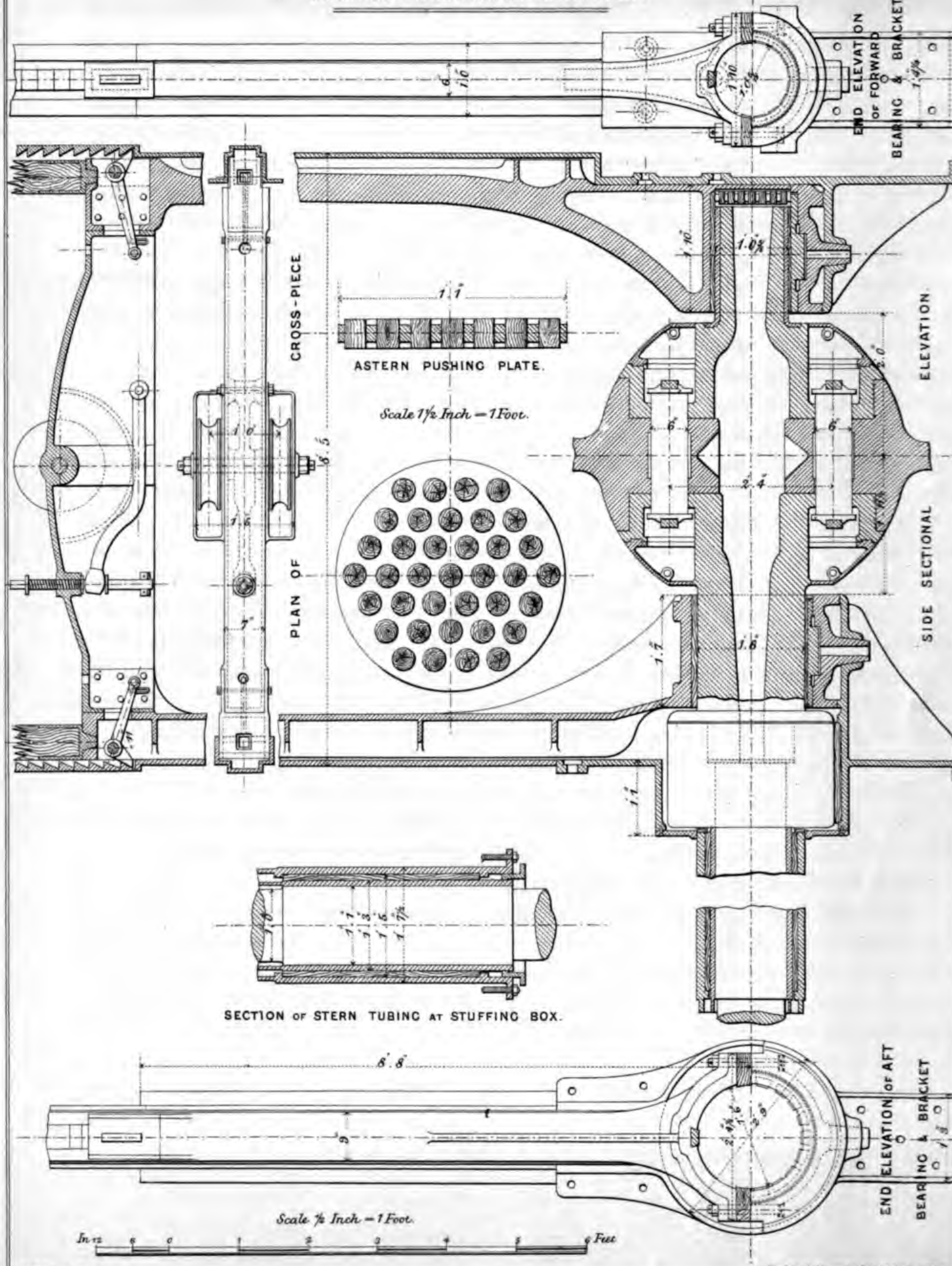
Stern Shaft.—This shaft passes through the stern tube, and that portion of it is encased in a gun-metal tube for the working bearing surfaces on the strips of wood already described; there are two purposes for the casing referred to, one is to prevent rust, and the second, re-turning or re-facing the working bearings without affecting the diameter or strength of the shaft. The portion of the shaft not cased at the extremity of the tube is where the "driver" is fixed, and the surface of the largest diameter at the opposite end is the bearing inside the hull; the disc is the half-coupling and is connected to its fellow by bolts and nuts as is the usual practice.

Thrust Shaft.—This "length" of the shafting is situated in the hull next to the crank shaft, and therefore bears the same relation to the engines as the stern shaft does to the propeller, their extremities being the limits of the transmission of the power developed.

Plate 27

DETAILS FOR SCREW PROPULSION.

BY MESSRS HUMPHRYS & TENNANT.



N. P. Burgh, Draw.

Newbery & Alexander, lith.

E. & F. N. Spon, 48, Charing Cross London.

It will be noticed that some portion of the shaft has rings formed on it; these are often turned out of the solid to ensure the greatest strength. Their purpose is to resist the thrust of the screw-propeller by being in contact with the bearing surfaces in front of each ring; so that the united areas of these front surfaces are equal to one larger ring or disc of equal area, and much more safe in their use than the single surface would be; there is of course the liability that the first ring receives the greatest pressure, and hence the most friction, but this is a question that we have dealt with in the chapter on "thrust blocks."

Details for Screw-Propulsion, by Messrs. Humphrys and Tennant. Plate 27.—It sometimes occurs that two firms unknowingly are constructing machinery of similar kind and purpose at the same time also, and thus the dimensions of the several details as fixed on by each designer, are interesting as a comparison as well as instructive. It is for this reason we have introduced the Plate 27, which illustrates a lifting frame, stern and rudder-post brackets, boss of propeller, and stern and shaft tubing, with a portion of the shaft, for a Griffiths' screw-propeller of precisely the same diameter—16 feet—as those details belong to in the preceding Plate 26.

Lifting Frame.—This is shown by a sectional elevation, plan, and end views. The propeller bearings are fitted with lignum-vitæ strips, entirely differently arranged to any other example we have hitherto illustrated or described. The forward bearing has nine strips below the centre line, two on it, and one at the top of the bearing. The mode of securing them is the usual kind, as shown by the end view. Of similar arrangement is the aft bearing, but only eight strips are inserted below the centre line. It will be noticed that the strips on this line are of peculiar form, as a comparison with the remainder, as, indeed, they are to any other example. The novelty is that these strips are distance pieces between the cap and supporting portions, and are secured by the bolts passing through them as depicted; they are therefore applied for two purposes at once; the first is as portions of the bearing surfaces, the second as adjusting strips between the connexions of the upper and lower portions of the bearings. The connecting bolts and nuts are the usual type, and pins over the nuts prevent their looseness.

The sides or perpendicular portions above the bearings are rather differently proportioned and shaped than the general form and dimensions, and are separate from the cross piece also, being connected thereto by bolts and nuts. The cross piece, it will be seen from its plan, clasps the extremities of the sides, and the bolts pass through the metal of both portions with the heads inside, but in some instances they are reversed in position, or with the nuts inside.

Returning now to the sectional view of the cross piece, we notice its fittings. The stop lever is shaped rather more simply than that in Plate 26, but the mode for raising and lowering it is precisely the same. The catch levers are supported by pins, and the

india-rubber loops are again introduced, as before, to keep them in position. A portion of the ratchet plates and fixing stays are depicted, also the rope pulleys and main pin.

Looking at the side view of the two cross pieces which we compare, a difference of opinion evidently prevails with the two firms; one prefers the upper edge to be curved upwards, while the other curves the lower edge downwards, and the opposite edges are straight across. The Messrs. Ravenhill also cast their frame entire with the caps, but Messrs. Humphrys cast the three portions—sides and cross piece—separate; so that the former firm deems a single casting and risk of its being a "waster" preferable to separate details connected by bolts and nuts, as by the latter firm; but both, of course, ultimately accomplish the same result.

STERN-POST BRACKET.—To economise space in the Plate this bracket is shown in the position for which it is constructed, and as its outline and arrangement is much as that in the Plate 26, there is no novelty hidden. The back part, it will be seen, is separate from the bearing portion, and the connexion is made by counter-sunk studs as depicted; there is, of course, an advantage with this, that the pattern of the bracket can be more simply moulded than if it were formed for a single casting only. Of course the end view shows the number of bolts used for securing the bracket to the post, and also its general form above and below the propeller bearing, which is very similar to that view in the Plate 26.

RUDDER-POST BRACKET.—The shape of this detail bears no resemblance to that for the same purpose previously illustrated; being, indeed, a striking contrast of the ideas of two designers, each seeking to attain one result by different arrangements. The sectional view of the bracket claims no attention beyond that it is properly designed with fitting strips and ribs below and above the bearing portion; but the end view does demand especial notice on account of the outlines above and below the seat for the framing being duplicates, or widely different to those portions in Plate 26.

STERN AND SHAFT TUBING.—There are not much in these details to demand any extended notice, for they are of the usual order and arrangement *in toto;* so for that reason we have omitted the transverse sectional and end views, because their outlines are much as those in Plate 26.

PROPELLER BOSS.—The form of the boss proper is nearly globular, and the connexion and adjustment of the blades of the propeller are by the wedges and key arrangement, and hand holes suitably formed and covered are also provided on the boss.

The forward gudgeon driver and shaft are of the type that has been fully noticed; but the aft gudgeon is a little different in its construction, being similar to that by Messrs. Watt, as illustrated in Plate 25, at page 138, where, as in this case, the gudgeon is encased with a tube to allow for the renewal of the working surface when requisite.

Curiously enough, too, Messrs. Humphrys and Messrs. Watt have both agreed about

the best means to resist the stern or aft thrust of the propeller, which is depicted at a large scale in this Plate, and also in Plate 25, being a disc perforated, and the holes fitted with lignum-vitæ circular blocks shaped with the grain "end on."

We may, perhaps, better complete our description of these details by stating that all the metal portions are of gun-metal, as those in Plates 25 and 26.

COMPARATIVE DETAILS FOR SCREW-PROPULSION, FITTED TO HER MAJESTY'S SHIP "WARRIOR," BY MESSRS. PENN, AND TO HER MAJESTY'S SHIP "HECTOR," BY MESSRS. NAPIER. Plate 28.—Of course it will be remembered that the arrangements of these details are depicted in the Plates 21 and 22, at pages 129 and 133, and therefore their use is apparent; but our present purpose is to compare the practice and proportions as carried out by two eminent firms in England and Scotland; which the present plate fully illustrates at a larger scale than before.

To begin with: Messrs. Penn's screw-propeller is 24 ft. in diameter, and the engines to work it are 1250 nominal horse power. Messrs. Napier's screw-propeller is 20 ft. in diameter, and the engines 800 horse power nominal. From these proportions we have, that Penn prefers 52·0833 horse power per foot of the diameter of the screw, and that Napier thinks 40 horse power sufficient.

On glancing now at the plate, we refer first to the aft propeller gudgeon bearings: here we see that the bearing by Penn is 1 ft. $3\frac{1}{2}$ in. diameter; but by Napier it is 1 ft. 5 in. Taking next the lengths of the strips of lignum-vitæ, Penn's practice is 1 ft. $6\frac{1}{2}$ in., while Napier's is 1 ft. $4\frac{1}{4}$ in. The arrangements of these strips are more different than their lengths, for Penn prefers 9 narrow strips below the centre line, and 3 wide ones above it; but Napier thinks that 18 strips of equal widths and equidistant apart the better plan. The surfaces of these strips as frictional bearings can thus be computed:

Penn's—consists of 9 lower strips each 2 in., and 3 upper 4 in. wide, all 18·5 in. long; then $9 \times 2 = 18$, and $3 \times 4 = 12$; after $18 + 12 = 30$, then $30 \times 18{\cdot}5 = 555$ square inches of bearing surface.

Napier's—consists of 18 strips; each 2 in. wide, and 16·25 in. long; then $2 \times 16{\cdot}25 = 32{\cdot}5$, and $32{\cdot}5 \times 18 = 585$ square inches of bearing surface.

The tubing into which these strips are inserted must next be compared. In this case both makers have agreed pretty fairly, for in each example stops or lugs over and under are cast on to prevent the tube from turning on its seat; and the fitting surfaces, too, are nearly the same; the modes of retaining the strips of wood, however, are a little different, as Penn has stops at one end only while Napier has stop rings at both ends.

The astern thrust plates, also, are evidences of two ideas. Penn adheres to his clever invention—the lignum-vitæ bearing—the wood being contained in a disc of metal; but Napier omits the wood and uses the metal only.

Next comes for notice the lifting or surrounding portions for the tubes; here both

makers seem to have concluded alike for the outline, and with good result too, for scarcely any metal is wasted or put to a disadvantage; they agree, also, about the position for the connecting bolts, and that single nuts are sufficient. There are two bolts on each side; their diameters are—Penn's, 2⅜ in., and Napier's, 2¼ in.

But as to the proportions of the facing strips on which the lower portions of the bearings rest, the two makers differ in opinion and practice evidently. For example, Penn has a facing strip directly aft of the guide-piece—inserted in the bracket—and one at the extremity, forward; but Napier arranges these strips directly fore and aft of the length of the bearing surface.

The rudder-post brackets in both examples are nearly duplicates in form, and their sizes, of course, are apparent from the scales being the same.

Forward from this we next notice the comparative features of the forward gudgeon bearing. The general outlines being almost similar to the aft bearings, we shall confine our conclusions to dimensions only here, as our previous descriptive remarks apply in this case also.

First, then, as to the diameters of the bearings. Penn's is 1 ft. 11½ in., and Napier's 1 ft. 10 in.; the lengths of the strips of wood, respectively, are 1 ft. 8 in. and 1 ft. 3½ in.; and their widths thus, Penn's 11 lower strips each 2½ in., and 3 upper each 6 in.; Napier's 18, each 2½ in.; then the surfaces are, Penn's $2{\cdot}5 \times 11 = 27{\cdot}5$ and $6 \times 3 = 18$; after $27{\cdot}5 + 18 = 45{\cdot}5$, and $45{\cdot}5 \times 20 = 910$ square inches. Napier's $2{\cdot}5 \times 18 = 45$, then $45 \times 15{\cdot}5 = 697{\cdot}5$ square inches. Diameter of connecting-bolts: Penn's 2½ in. (4), and Napier's 2¾ in. (4). Messrs. Penn, it will be seen, use a forward thrust-plate, formed as a ring of gun metal, with solid cylinders of lignum-vitæ passing through the metal at proportionate distances apart; while Messrs. Napier—not as in the case of the aft thrust-plate, substitute metal only—leave out any means of resistance entirely.

The connexions of the brackets with the stern-posts are not similar. Penn, it will be seen, casts a tube on to the back of the bracket, where Napier omits it, and uses an angle ring of wrought iron on the forward part of the post instead, to support the stern tubing.

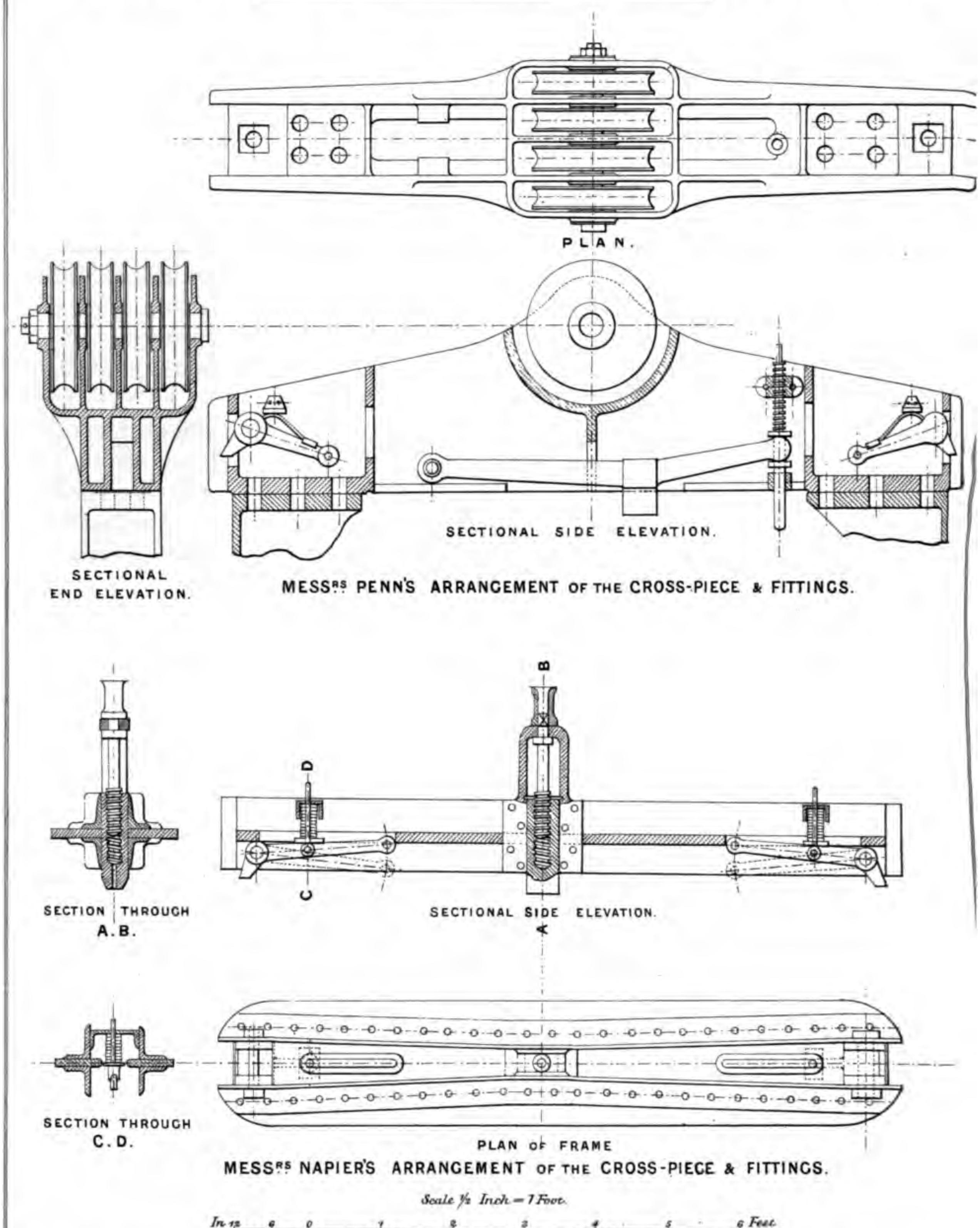
Next we compare the connexion of the side pieces with the caps of the bearings. Messrs. Penn cast the sides and caps together of gun metal, but Napier, having an eye for economy, casts only a small portion of gun metal, with the caps, and connects thereto wrought-iron sides, secured by cross keys.

Messrs. Napier, still careful, have catch levers over the caps, with india-rubber springs to keep the levers to their duty, whereas Penn omits them at this locality.

The cross piece and its fittings by the two firms now come under consideration. Messrs. Penn prefer to make the entire details of gun-metal, excepting the steel springs over the catch levers, which are preferable to the india-rubber loops under the levers, as

COMPARATIVE DETAILS OF SCREW PROPULSION.

FITTED TO H.M.S. "WARRIOR" BY MESSRS PENN. & TO H.M.S. "HECTOR" BY MESSRS NAPIER.



N.P. Burgh, Direx.

Newbury & Alexander, Lith. 43, Castle St Holborn

E & F. N. Spon, 48, Charing Cross, London.

often used. The cross piece is cast in one casting separate from the sides, which are connected by bolts and nuts as depicted. The elevation presents a neat appearance and the plan a thoughtful arrangement. Of far different aspect is the example by Napier, although the arrangement is equally an evidence of consideration. The cross piece is of wrought-iron plating and angle iron; connected as shown by the sectional views and the plan. The outline of the elevation forms a contrast with Penn's, as also does the plan.

Next comes the details: Napier's idea on the mechanical matter for stopping the blade of the propeller, and Penn's opinion on the same subject, are evidently rather apart from each other. Penn considers that the lever and screwed-rod motion is as efficient as need be; but not so Napier, he prefers direct action, which he attains by a sliding stop portion: being a piece of gun-metal in a vertical groove in the centre of the cross piece; the motion up and down or for in and out of gear, is by a screwed rod within the slide; the screw hole being of suitable length, so that on turning the rod around, the slide is moved in the required direction.

Now let us compare these arrangements a little closer; Penn has a lever hung on a pin, which pin must of course be secured by either a nut or washer and pin; Napier in the place of these has a sliding piece of gun-metal fitting in a groove or hole formed of wrought-iron, and thus the cross piece is narrowest at this part, as the plan depicts. The slide-piece is screwed internally and thus that amount of work can be weighed against Penn's lever-pin and nut, while the lever and sliding piece may be taken as about equal in labour. Messrs. Penn provide a screwed rod, and so does Napier, to raise the stop piece; therefore the only difference that remains, is in the modes for supporting these rods; the former has a fixed block for the screw, and a guide piece for the opposite or lower end; but the latter has a small bracket only. We have therefore evidence that although the two firms employ two separate arrangements for one purpose, in point of labour and material they agree pretty well.

The springs for the catch-levers are the details we compare next: Penn has the simplest of methods, being merely a flat spring bent sufficiently to keep the lever down and allow for its rise; but Napier again carries out his arrangement as over the caps of the bearings. On contrasting these two kinds of springs we unhesitatingly award the laurels to Messrs. Penn, for Messrs. Napier use nearly double the amount of detail, and therefore a proportionate amount of labour to attain the same result.

Our notice of comparison next extends to the "holding-down gear." Messrs. Penn use wooden fixing stays tipped with gun-metal; the lower end of each is fixed in the hole provided for it at each end of the cross piece; the upper end is held in position by a set screw, which bears against a bracket secured to resist the pressure requisite to keep the framing and propeller down.

Messrs. Napier's liking for the use of wrought iron extends to the holding-down gear

also; for they have made the fixing stays of wrought-iron bars, and connect them to the cross piece with gun-metal pins. The upper ends are secured in their vertical position by gun-metal set screws and nuts that screw through gun-metal bushes fixed into horizontal cast-iron brackets. The diameter of each of the set screws by Penn is 2¼ in.; but Napier has made his 3 in. in diameter; he uses set nuts also, in the place of the collar under the bracket as by Penn.

It will of course have been recognised that Messrs. Penn use the fixing stays for the one purpose of holding down the framing only; but that Messrs. Napier utilize their fixing stays in another direction, that has been shown in the Plate 22, at page 133; it being that when these stays are released they are not withdrawn as with Penn's practice, but meet on the centre line and form a loop to lift the frame and propeller by; thereby dispensing with the rope pulleys. We may notice also that the diameter of the pulley pin by Penn is 4 in., while the diameter of each of the stay pins by Napier is 2¾ in.

Holding-down Gear fitted to Her Majesty's Ship "Warrior," by Messrs. John Penn and Son. Plate 29.—This plate, although in its proper place with this chapter, is a companion to Plate 21, at page 129.

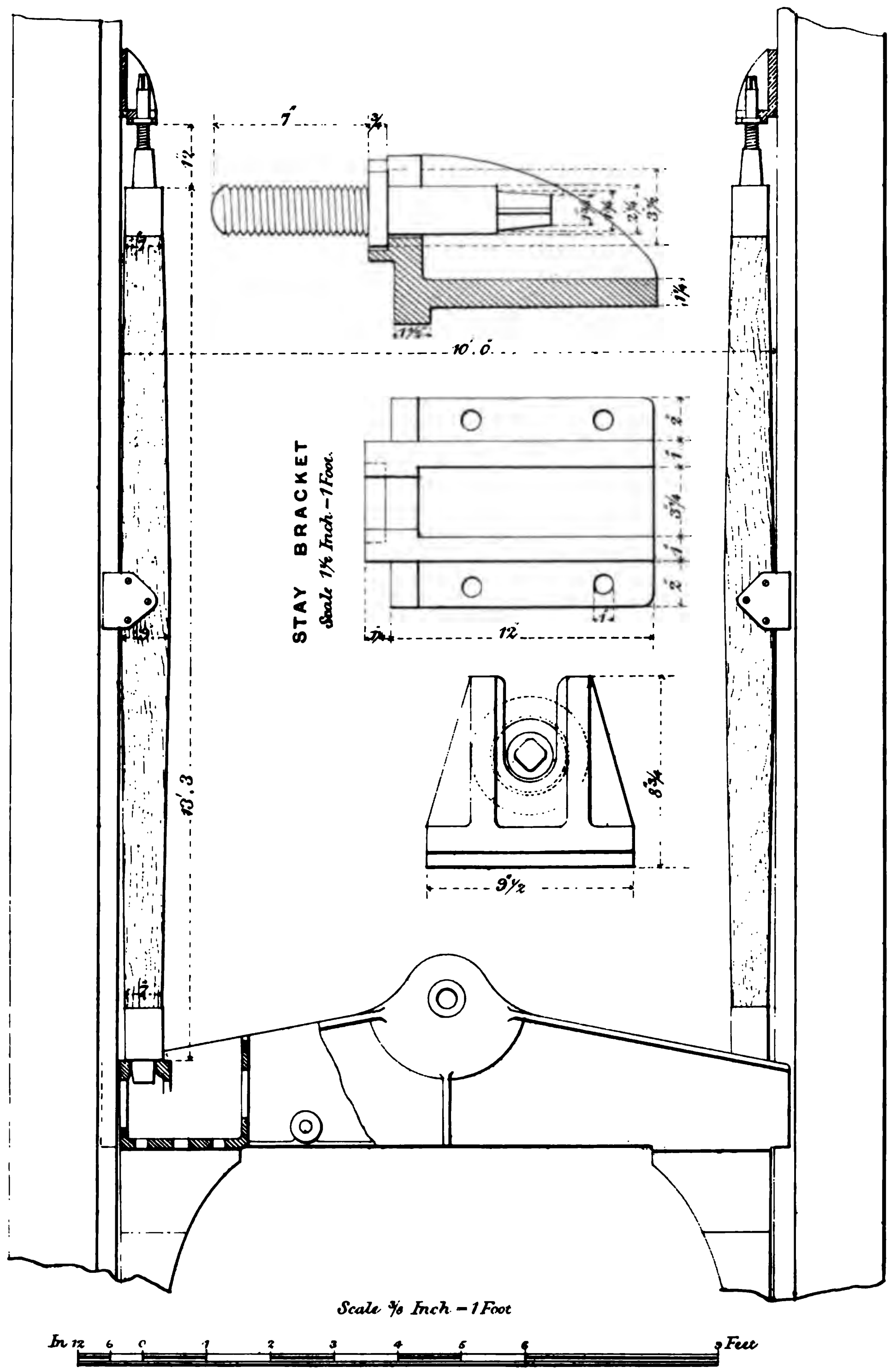
The arrangement of this gear is very simple and efficacious, as it consists of two wooden stays, tipped and guided by suitable portions of gun-metal; the guide pieces are merely plates of metal secured to the stays by screws. The lower tip is partially hollow into which the stay is secured, and the solid portion below fits into the hole provided for it in the cross piece of the framing. The top portion has been already fully commented on in page 149. The bracket is of cast iron, and is bolted to the stern and rudder posts.

The simplicity of this arrangement lies in the easy method available for the disconnexion of the stays—or, if a better term, the release of the framing—for the set screws are the only portions that have to be *unlocked*, which is merely screwing the screws downwards to release the collars from the bracket projections, and then the frame and propeller can be raised. Similarly by this simple means the frame is secured when down by screwing up the screws, and thus causing their collars to bear against the projections appointed. As the rudder and stern posts and cross piece of the frame are shown, the arrangement of the gear can be fully understood and appreciated.

Details of a Wrought-iron Lifting Frame for a Screw-propeller Nine Feet in Diameter. Plate 30.—We introduce here another striking illustration of the fact that gun-metal, although the best of general composite materials to resist corrosion in sea-water, is not really important enough to demand an entire use for the purpose under notice. Indeed, if we want evidence of this fact in a practical manner, we can take the state of the wrought-iron steam-ship *Wolf*, that sank in October, 1867, and when raised, in September, 1868, the hull and machinery were found to be but very little affected by the corrosive action of the sea-water. We learn, therefore, that when cast and wrought

HOLDING DOWN GEAR. — H.M.S. "WARRIOR" 1250 HP.

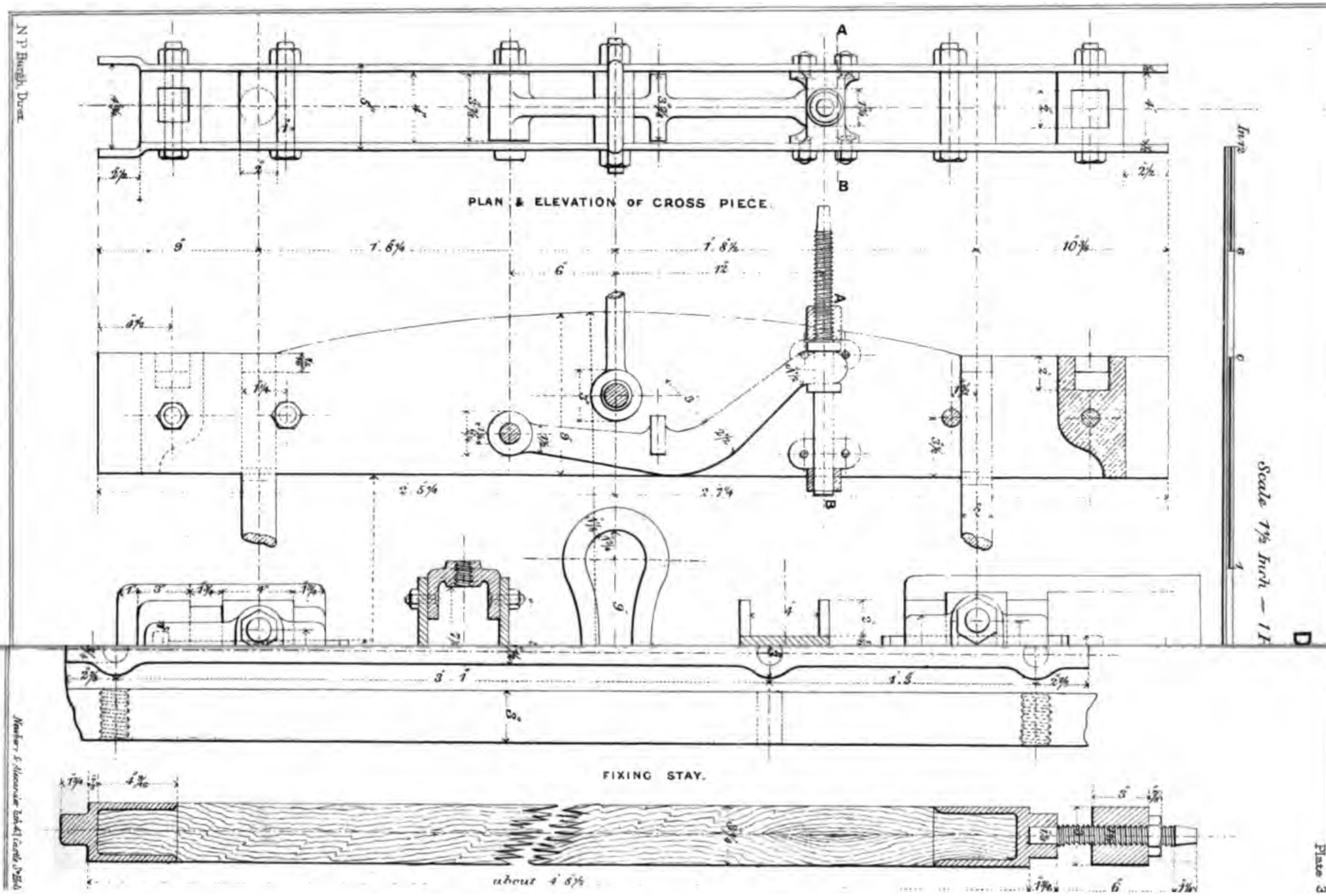
BY MESSRS. JOHN PENN & SON.



h. Direx

Newbery & Alexander lith. Castle St. Holborn

E. & F. N. Spon, 48, Charing Cross, London


N P Burgh, Direx.
PLAN & ELEVATION OF CROSS PIECE.
A
B
FIXING STAY.
about 4' 8⅞
Scale 1½ Inch — 1 F
D
Newbery & Alexander Lith. 4 Castle St. Holb.
Plate 3

iron are submerged sufficiently below the atmospheric influence on metals, that the natural corrosion of the sea-water is of much less effect than when assisted by the atmosphere.

Of course the properties of gun or composite metal present a nauseous and poisonous taste, and, as with copper, the shell-fish do not care to adhere to the surfaces of either metal, or as they congregate with impunity on wood and iron when both are submerged; and even the drawback of the uneven surface of shell-fish as a resistance to the forward motion of the hull gives no absolute cause to use such a costly compound of metals, in the place of cheaper kinds, which, with occasional cleansing, are equally applicable. And it is for this reason that wrought and cast iron are now being used largely for screw-propellers and their immediate details, where gun-metal was once held supreme.

Lifting Frame.—The forward and aft propeller bearings are of gun-metal, fitted with wide strips of lignum-vitæ, that are dovetailed into the tubing, and secured by rings of gun-metal, fastened by studs situated between the strips of the wood at both ends of the tubes. The cap and supporting half of each bearing are connected by bolts secured by double nuts, and the lower portion of each bearing has the usual guide lug passing through the seat of the bracket. The astern thrust of the propeller gudgeon is resisted by a metal plate, having a square projection on it which fits into the back of the bearing, to prevent the plate turning around.

The connexion of the caps with the cross piece is by the wrought-iron round rods, secured to the caps by keys passing through the bosses provided thereon. The cross piece is the simplest we have yet recorded, being merely two wrought-iron plates, with cast-iron distance-pieces at each end, which serve also as the seats for the fixing stays. The mode for attaching the side rods to the cross piece is both simple and secure; each rod is enlarged in width equal to that of the cross piece, and the thickness is the diameter of the portion below. The sides are recessed for a portion of their depth into the narrow part of the head of the rod; the projections above and below the recess of course renders the connexion perfect; while a bolt at the side of the head secures the sides of the cross piece. The stop lever is the usual kind, and the connexion of the screw-rod support and guide is shown by the cross section below.

Next we notice the lifting loop, which is shown most explicitly by the transverse section of it at the end of the cross piece; it is connected by a pin and nuts at each end, with a distance washer between the eyes.

Stern and Rudder-Post Brackets.—These are *cast iron*, the price of which is much less than gun-metal, being indeed in the ratio of 1 to 6, and for this difference doubtless the cheaper material will eventually be more often used for this purpose than hitherto; of course the difference in the weight and strength of the materials can be nearly balanced, inasmuch that the weight of a cubic inch of cast iron is ·263 of a pound, and the same size of gun-metal is ·3177 lb., also the full tensile strength of cast iron is 20,000 lb., while

gun-metal is 35,000 lb. breaking strain on the square inch. From this we know, that if cast iron is 1 in weight, gun-metal is 1·2; and in relation to strength, cast iron is 1 to 1·75 of gun-metal; so that if the latter metal is stronger than the former it is heavier, so that what is saved by weight is due to the strength of the metal only; and taking next the cost of the material into consideration: the weights being nearly equal for the equal strength; the price of a gun-metal bracket is six times that for cast iron, with no advantage proportionate to warrant its universal use in the place of the latter metal.

But, as we stated in page 143, we do not see any reason for using the brackets of any kind; for the supports for the framing can be *forged* with the posts, cheaply and strong, and more simple than connecting the brackets to them by bolts and nuts.

In the example before us each bracket is secured by flanges clasping the posts, and bolts passing through the whole make firm the connexion. The supporting portion of the brackets are simple, and as little material as sufficient strength requires. Ribs and fitting strips are suitably arranged, so that the outline and the arrangement are worthy of adoption when required.

Fixing Stay and Cross-Bar.—The arrangement of the tips of this stay is precisely as that in page 134, shown by Fig. 40, being gun-metal tips and securing or set screw and nut. The cross-bar is of wrought iron and is used in this case instead of brackets through which the set-screws pass.

As we have fully dimensioned all the details in this Plate, we have not referred to the proportions in our description, but a fair comparison can be made by noticing the dimensions given in pages 137 and 138 in relation to the example illustrated by Fig. 41 in the former page.

of the temperature of the water in the trough in a given time, caused by the rotati the axle, the quantity of water being exactly two cubic feet in each case, and at the initial temperature. In estimating the pressure to which the bearings were subj 1 square in. of bearing surface was used, and the total weight on each bearing gav pressure in lbs. per square inch.

The particulars of the experiments are given in the Tables, and the general re obtained are as shown:—

Description of Bearing.	Pressure per square inch.	Time of Running.	Result of Experiment.
	lbs.		
Brass on Iron . . .	448	30 mins.	Little or no cutting.
Brass on Iron . . .	675	1 hour.	Cut and abraded.
Brass on Iron . . .	4480	. .	Seized and stuck fast immediately.
Lignum-vitæ on Iron .	1250	36 hours.	No signs of wear; original slight scratch not worn
Box on Brass . . .	4480	5 mins.	Not cut.
Lignum-vitæ on Brass.	4000	5 mins.	No injury. This specimen is shown full size by A, Fig
Snake-wood on Brass .	4000	5 mins.	No injury. Shown full size by A, Fig. 43.
Cam-wood on Brass .	8000	5 mins.	No injury. Shown full size by B, Fig. 43.

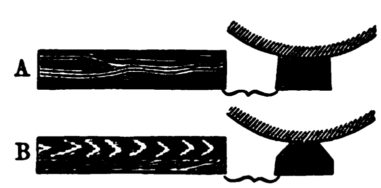
TABLE OF EXPERIMENTS ON FRICTION OF BEARINGS.

Description of Bearing.	Area of Bearing.	Total Pressure.	Pressure per square inch.	Time of Running.	Result of Experiment.
	Sq. in.	lb.	lb.	Minutes.	
Brass on Brass	$\frac{1}{8}$	448	3584	15	
Box on Brass	1	560	560	10	Marks not out.
Box on Brass	$\frac{1}{8}$	448	3584	5	Not cut.
Box on Brass	$\frac{1}{8}$	560	4480	5	Not cut.
Box on Brass	$\frac{1}{8}$	560	4480	5	Not cut.
Box on Brass	$\frac{1}{8}$	672	5376	0	Cut and abraded; side grain.
Box on Brass	$\frac{1}{8}$	672	5376	5	End grain; not cut.
Lignum-vitæ on Brass . .	1	672	672	15	Scratches made with tip of l not touched.
Lignum-vitæ on Brass . .	$\frac{1}{8}$	560	4480	5	Cut a little.
Brass on Brass (salt water) .	1	448	448	30	Little or no cutting.
Brass on Brass (salt water) .	$\frac{1}{8}$	448	3584	6	
Brass on Iron	1	448	448	5	Cut.
New Brass on Iron . . .	1	560	560	10	Cut.
Brass on Iron	1	675	675	60	Cut and abraded.
Brass on Iron	$\frac{1}{8}$	560	4480	0	Would not revolve; seized stuck fast immediately.
Babbitt's metal on Iron . .	$\frac{1}{4}$	400	1600	8	Rolled out sideways.
Kingston's metal on Iron .	$\frac{1}{4}$	400	1600	6	Rolled out sideways.
Box on Iron	1	448	448	30	No perceptible wear.
Box on Iron	$\frac{1}{8}$	448	3584	19	
Box on Iron	$\frac{1}{8}$	448	3584	5	But little worn.
Lignum-vitæ on Brass . .	1	560	560	10	Mark not out.
Lignum-vitæ on Iron . . .	1	1250	1250	2160	No signs of wear; original sli scratch not out.
Lignum-vitæ on Brass . .	$\frac{1}{4}$	1000	4000	5	No injury.
Snake-wood on Brass . . .	$\frac{1}{4}$	1000	4000	5	No injury.
Cam-wood on Brass . . .	$\frac{1}{8}$	1000	8000	5	No injury.

In the foregoing experiments, the principal object was the prevention of the serious evils attending the ordinary bearings of screw shafts; and the circumstances under which the experiments were conducted were therefore arranged to correspond as nearly as possible with those experienced in the actual working of ordinary screw shafts; the experimental axle was wholly immersed in salt water, and was driven in all cases at a speed equivalent to that of screw shafts on the largest scale.

The result obtained from these experiments was so definite and satisfactory, that arrangements were immediately made for the application of the wood bearings to the screw shafts of Her Majesty's ships, and these have in every instance succeeded beyond expectation.

The general results therefore appear to point to the use of a plentiful supply of water, to carry off the heat caused by the friction of the bearings; and in the cases where this can be accomplished thoroughly, so as to carry off the heat as fast as it is generated, a brass journal revolving in hard wood bearings is practically perfect, showing no perceptible wear under a much more severe pressure than is usually met with in machinery. The two rubbing surfaces appear in reality to run without any lubricating material between them, and the water acts merely as a conductor to carry off the heat as rapidly as it is produced.



Form of the Wood Strips used as an Experiment for frictional bearings by Mr. Penn.

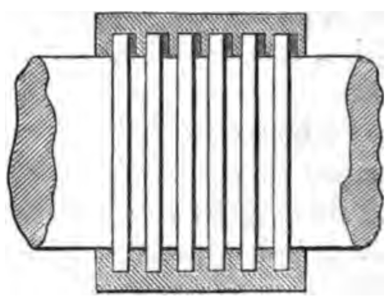
Fig. 43.

The pieces of wood, shown by Fig. 43, that had been used for trial, seem apparently insignificant, and their small size might cause the experiments to be looked upon as not sufficiently practical; but it had been found in the first trials that a pressure of 1000 lb. per square in. on a piece of wood of 1 square in. area would not wear out the scratch of a pin, after running 24 or 36 hours; and the only available method at the time of increasing the pressure per square in. had been to reduce the size of the pieces of wood, retaining the same weights in the apparatus with which the experiments were made. The slips of wood of 1 in. length had accordingly been reduced in width to $\frac{1}{4}$ in. in the expectation that a few minutes would suffice to give a definite result, but no wear could even then be produced; the area was then reduced to $\frac{1}{8}$ square in., and still no abrasion took place under a pressure of 1000 lb. or 8000 lb. per square in.; the experiment was limited to this pressure by the slipping of the strap upon the pulley by which the shaft was driven. The little bit of wood used in this experiment had been left running for 3 hours at a speed of 260 ft. per minute, and had been tried in both fresh water and salt water, the latter salter than the sea, with no difference in the result. A brass bearing that had been driven at the same speed had been cut immediately at a pressure of 220 to 230 lb. per square in., so remarkable was the difference between wood and brass; and Babbitt's soft metal,

Kingston's metal, and other mixtures, had also been tried, but were not capable of working under a pressure at all approaching that admissible with the wood bearings. Several soft woods had been tried, all of which stood well; and among them poplar, which was a very soft wood, stood a heavy pressure with very litte wear.

Of the various kinds of wood that have been tried in the experiments, lignum-vitæ appears to be very satisfactory, and nearly as good as any, and it has the practical advantage of being less expensive, and readily obtainable.

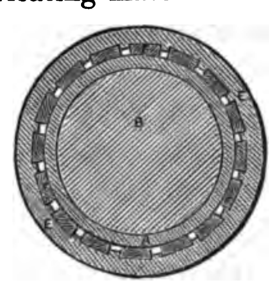
Another application of the wood bearings may be mentioned, which has been practically tried and found very advantageous. The bearing which receives the thrust or propelling effect of the screw in the direction of the vessel's motion is formed of a series of collars on the shaft, running in corresponding grooves in the brasses, which have been found to wear very seriously, in a similar manner to the main bearings of the screw shafts. The thrust bearing of the *Himalaya*, which is shown by Fig. 44, had the brasses worn away longitudinally nearly $\frac{3}{8}$ in. at each collar, and this was repaired by the engineer whilst out on the voyage, by putting in a set of rings of lignum-vitæ as an experiment, filling up the worn space, as shown in the upper half of Fig. 44. The wood was merely sawn into half rings, the lower pieces being slipped in from above without lifting the shaft from its bearing. This plan answered completely, and no perceptible wear was found in the wood rings after the voyage home, the original saw marks not even being effaced; and the bearing proved so satisfactory, although only temporarily constructed, that the vessel has gone to sea again without any alteration. In this case the wood bearing was allowed to work most of the time with oil alone as a lubricating material.



Sectional Elevation of the thrust block of the Screw shaft of H.M.T.S. *Himalaya* when fitted with *semi-circular* Strips of Lignum-vitæ.

Fig. 44.

The method in which the wood was originally, and is now, employed is shown by Fig. 45: the ordinary brass bush E has longitudinal dovetailed grooves formed on its face, which are filled with strips of hard wood FF; lignum-vitæ has been generally used. The strips of wood are about $2\frac{1}{2}$ in. wide, with a space of about $\frac{3}{8}$ in. between each, and stand out $\frac{1}{4}$ in. from the surface of the brass; water is kept constantly flowing between the strips along the shaft, and forms the only mode of lubrication, and this is found to prevent all tendency to heating or wearing of the journals.



Mr. Penn's original arrangement of Lignum-vitæ bearings for Screw-propellers and Shafting.

Fig. 45.

The foregoing remarks and tables are much the same as those contained in my paper on

between the after end of the screw-propeller and the banjo frame, to take the astern thrust.

* In conclusion, we must add that it is remarkable that such an important invention, which has increased so immeasurably the efficiency of the screw-ships in Her Majesty's navy, should have left the hands of Mr. Penn practically perfect in its first application, for neither the inventor nor any other person, so far as we can learn, has as yet improved on this beautifully simple application of wood for submerged bearings.

STERN TUBING, LIGNUM-VITÆ BEARINGS, AND PORTION OF SCREW SHAFT, FITTED TO HER MAJESTY'S SHIP, "WARRIOR," BY MESSRS. JOHN PENN AND SON, PLATE 31.—†The arrangement of these details fully portray the present practice of the leading firms of England and Scotland; but before we enter into the description we will dwell a little on the principles on which the success of these bearings are founded.

First, then, what are the circumstances to be considered with screw-propeller bearings? They are that the weights of the propeller and its lifting frame tend to produce a closer contact for the lower half surface of the bearing than the upper half; and therefore the modern practice as by Messrs. Penn, is to reduce the upper frictional surface in relation to the lower.

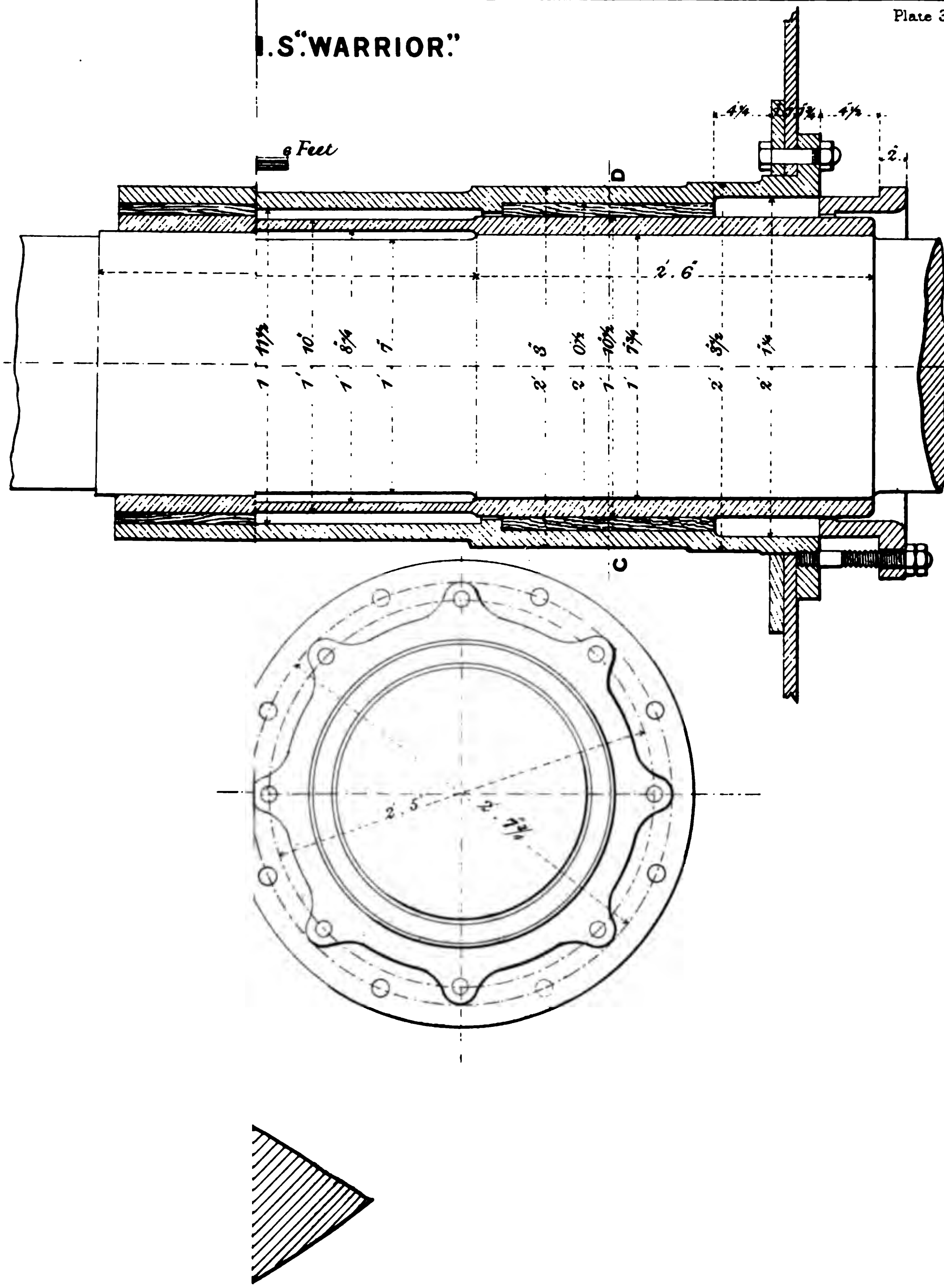
Secondly, what is the nature of the resistance of the frictional bearings in the stern tube? We must answer this by noticing that the screw shaft is merely a communicant of power to a revolving body at its extremity; which is of course the propeller; and that although the weight of the propeller causes a deflection of the shaft when at rest, a great deal of the downward pressure on the shaft is taken up by centrifugal action when the revolving motion occurs. But we will take this matter up a little more in detail, and to do so, let us suppose that we have a series of shafts whose total length is 70 diameters from the centre of the engines to that of the screw-propeller, which proportion is about the average practice. All the power that is transmitted by the cranks on to the shaft runs along its length, and of course is finally *reduced by bearing friction* to the *minimum* on reaching of the propeller. Now this *reduction* of the power is the vital point on which the whole affair hangs; for it is obvious that the power at the centre of the *aft* crank pin is amalgamated with what has been generated before; and from here the aft bearing and the thrust block absorb some of that power; next the shaft supports or "plummer blocks," take some more; and then the stern-tube bearings have their share; and finally the propeller bearings, if there are any, complete the plunder; and this "plunder" of the power, for we can give it no better expression, requires to be reduced to the least quantity possible.

We have now to consider where the greatest "plunder of the power" is situated throughout the shafting; of course the bearing surfaces inside the hull can be regulated

* Note by N. P. B. † By N. P. B.

I.S.“WARRIOR.”

Feet



N P. Burgh, Direx

Newbery & Alexander lith 43 Castle St Holborn

by manipulation, and artificial lubricant; but not so the bearings beyond that, and it is for that reason that Mr. Penn made a scientific hit when he used *natural* lubrication in the place of artificial for the stern shafting and propeller bearings.

The propeller, let it be remembered, is but the arms of a wheel without the rim. And thus the blows that the blades or arms give to the water over and under the horizontal centre line of motion are unequal in force; obviously then the vibratory effect must be an unequal centrifugal action, and that is the reason why the screw-propeller is said to "thump" sometimes. This "thumping" then becomes a matter of great consideration in relation to the frictional bearings next to the propeller; as the circumstance of friction is not only rotary but it is sideways too, and that to such an extent that brass bearings under brass have often been cut down sufficiently to interfere detrimentally with the original centre line of the shafting.

A practical demonstration of this has occurred with the original brass bearings of the propeller-shaft of Her Majesty's Ship *Cæsar*, engined 400 nominal horse power collectively, the propeller being hung in a lifting frame, where after six months' wear the inside diameter of the brass stern bush became oval to such an extent that vertically it was 1¼ in. deeper, and horizontally 1 in. wider than the original size, and the brass bearing encircling the shaft was grooved at intervals ¼ in. deep and of equal width; this then is a proof enough that bearings formed of brass on brass were the greatest drawback to the development of screw-propulsion that could ensue; and until that Mr. Penn introduced the wood bearings there was a cloud of despair hanging around the enterprise.

Returning again to the action of the propeller-shaft on its bearing, we may explain that when the propeller is hung in the lifting frame the propeller bearing often wears down more than the shaft bearing and thus the centre line of the former performs a circle around that of the latter, and therefore laterally an undue strain occurs.

But apart from this "unequal centrifugal action," there is the equal action to notice, inasmuch that when the propeller is "over-hung" the centrifugal motion is at its utmost limit. And to resist that, the bearing directly beyond, or inside, must be suitably proportioned in length so as to "hold" the shaft in true position during its motion.

The natural action of the propeller when over-hung we also noticed in page 103 of this work, were we stated that "if the shaft were loose in its bearings it would not only revolve on its axis, but also produce a centrifugal motion," so that although the gyratory motion is resisted by the bearing, the natural tendency of the propeller to cause the shaft to vibrate or "wabble" remains constant; indeed we should never lose sight of that fact when designing screw-shaft bearings.

Having now run through the leading principles in connexion with our present subject we turn next to the practical matters. It has been settled in our previous remarks that gun-metal on gun-metal for bearing surfaces are of no use, because the heat generated by

the friction, will waste the bearing, although almost every precaution may be taken to ensure water lubrication; but when lignum-vitæ bearings are used *the water softens the wood*, and the "thump" or "wabble" of the shaft caused by the propeller, is resisted by a gentle admission of the force imposed, and thus the harder surface, although pressing on the softer, does not cut into or impress such a result of contact, as if the receiving surface were of equal resisting property. Indeed the lignum-vitæ permits the metal to expend its "tear" and "grip" on the surface of the wood only; and if any heat at all is generated by that operation the water between the wood carries it off.

The next portion to consider is whether the *heat* generated by the friction is carried off *in toto* by the water flowing through the channels appointed, or if a certain amount of the temperature is not reduced beforehand by the action of the receding surface of the wood in contact with the metal; we must not overlook the fact also that while the propeller does *not* vibrate during its revolution, the force of the centrifugal action will be equal from the centre of motion; but when the "wabble" occurs, then the virtue of the lignum-vitæ is strained sufficiently to prove its worth, for if it were not so, the surface of the wood would give way to the utmost pressure imposed on it by the metal and *not* return again to its normal condition; whereas in practice the "wood holds its own" under all circumstances of motion. So that in consideration of these conclusions we are inclined to believe that the frictional heat is reduced to the minimum, first by the wood receding from the metal, and secondly, by the water in the channels absorbing it afterwards.

The illustration that we have under notice is the recent practice by Messrs. Penn, and fully depicts what is requisite to be considered in the adoption of lignum-vitæ bearings. The strips are dovetailed into their grooves, because it is presumed that when the extreme pressure comes on them they must necessarily expand laterally, and therefore the dovetail recess is the best form to resist that effect and prevent looseness of the strips. As the arrangement is dimensioned sufficiently for practice, we need not add further description to what has been given by Mr. Penn under his name.

thus the engines are converted into an auxiliary means with a proportionate amount of commercial gain.

Keeping this fact in mind let us dwell a little on the probable action of the blades in the water when they are set at an angle unsuitable for the highest propulsion of the hull to which they are fitted. Of course on starting they will strike the water sideways, or laterally disturb it, and thus disturb the aft volume also; and this side-striking will continue with a reducing effect until the speed of the hull agrees with the velocity of the propeller; when the blades will *cut* the forward current *without* disturbing either the side or aft currents. Obviously then if the angles of the blades are not in accordance with the velocity requisite for them to propel the hull at the highest speed with the least power, a great deal of the power is absorbed by the "side striking" being continued even when the blades are revolving at the maximum velocity proportionate to the force employed. It may occur also that the actual revolving speed of the screw will be more than what is theoretically required to propel the hull at a certain lineal speed; which difference or loss is termed "slip," and therefore the cause for the "slip" is that the "side-striking" disturbs not only those currents, but also the aft volume.

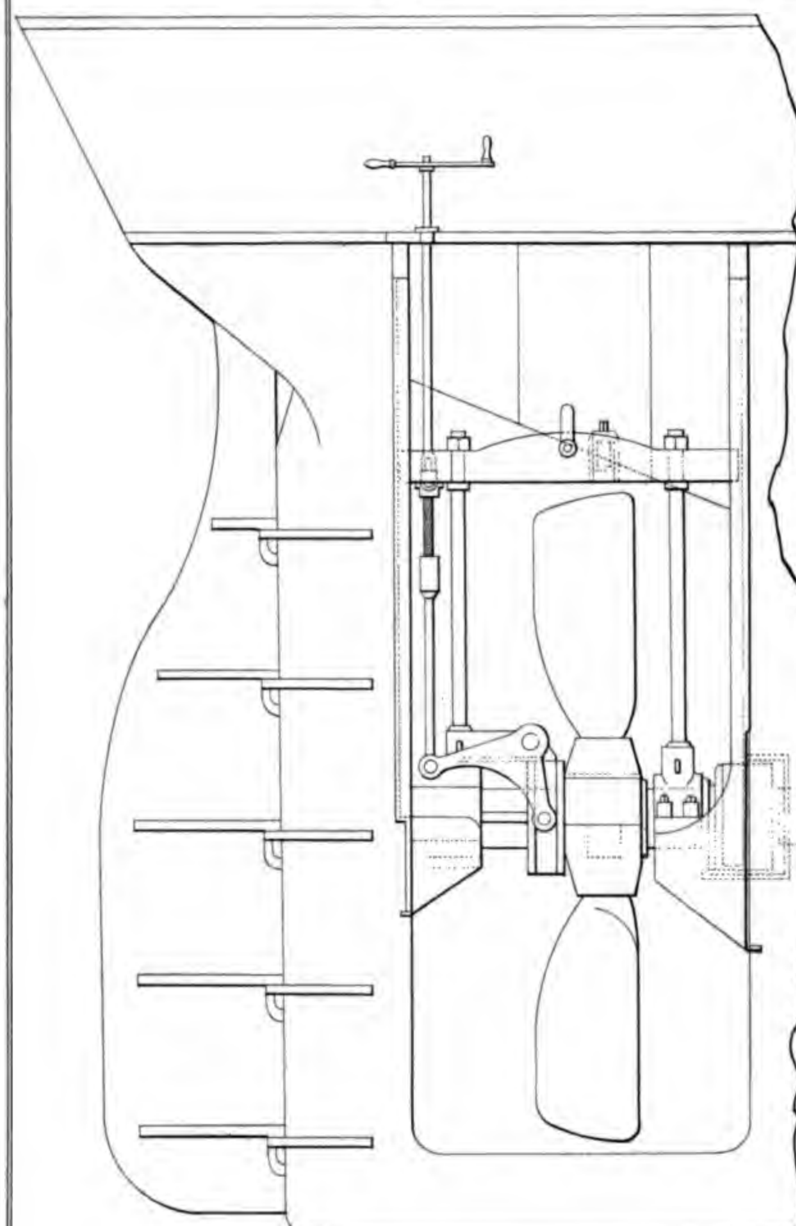
Now the aft volume is the main agent in the matter of screw propulsion, as it is the *resistance* which the screw blades bear against to push or propel the hull forward, and it is evident therefore that the progress of the hull will be increased with the same velocity for the propeller, if the aft volume is undisturbed; because it will then be what is termed "dead" or "solid" water, or of the greatest resistance to the backward thrust of the screw blades.

The type of propeller under notice is arranged to encompass all of the requirements that have been mentioned, by a mechanical contrivance which enables the engineer on deck to set the blades from their fore and aft position when at rest, to any angle that is best for their duty when at work.

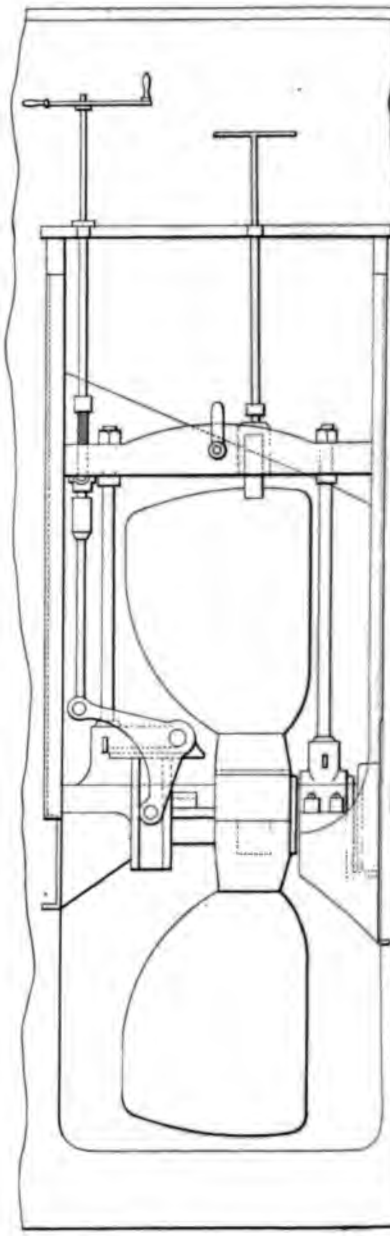
To enable this to be fully understood we next direct attention to the Plate 32, which illustrates the latest arrangement in this matter. The side sectional elevation illustrates the entire arrangement of the propeller, lifting frame, stern and rudder-post brackets, and the feathering gear; which is arranged thus: The boss of the propeller instead of being globular or zone shaped, is formed of two cylindrical bosses cast with the gudgeon, into which the securing portions of the blades are fitted. As each of these portions have levers formed with them, the bosses are grooved through on one side fore and aft to admit the levers to pass down into their seats. To prevent their return, and to secure the blades from shifting up and down, the grooves are filled with stop-blocks of metal that are fastened by bolts and nuts as shown in the side sectional elevation, by the section through the centre of the propeller, and in the plan. The levers are connected by two double-eye plates and pins to two projections formed on a sliding clutch, that surrounds the aft

COMPLETE ARRANGEMENT OF FEATHERING GEAR & PROPELLER.

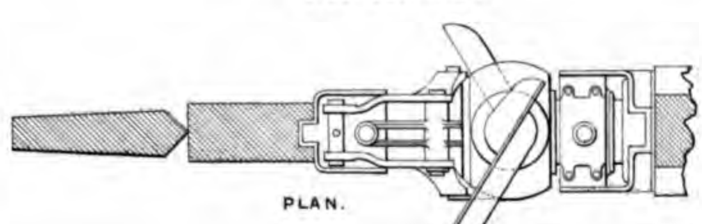
CONSTRUCTED BY MESSRS MAUDSLAY SONS & FIELD.



SIDE ELEVATION.

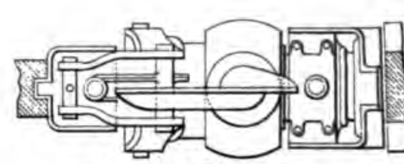


SIDE ELEVATION.



PLAN.

Angle of Blades when Propelling.



PLAN.

Position of Blades when Sailing

Scale 3/8 Inch = 1 Foot.

In 12 6 0 1 2 3 4 5 6 *Feet*

N.P. Burgh, Delt.

Newbury & ... Lith.

E. & F. N. Spon 48, Charing Cross London

gudgeon and revolves with it; this clutch is merely a ring of metal with a deep groove in the centre of its width, and within the groove is secured a non-rotary or sliding ring, the lower portion of which is cast separate, and fitted to the upper and secured thereto by bolts and nuts for the purpose of erecting it while the propeller gudgeon is hung in its bearings; these details are shown in the side elevation, and also in the end view of the clutch and motion gear.

The sliding ring is fitted with lignum-vitæ strips for the clutch ring to work against instead of metal, as the frictional contact is reduced thereby.

The sliding motion required for the clutch to turn the blades in their seats is attained from two bell cranks, supported in brackets cast with the aft side of the frames that guide the sliding ring also. The lower cranks are connected to the sliding ring by pins, and those above to a vertical motion piece which is hung from the lower end of the motion screw in the cross piece. The action, therefore, is thus: on turning the screw the motion piece descends, lowers the cranks, and those below shift the clutch and eye-plates which turn the levers formed with the blades in opposite directions, and of course return them to their former position when the screw raises the motion piece. The arrangement is, therefore, of the simplest order, while *all* the details can be examined without disconnexion, a matter of the highest importance at sea.

The plan shows the blades set at an angle, and the clutch forward; but the elevation depicts the blades fore and aft with the clutch back. In the elevation we have shown their relative positions also.

The bearings for the gudgeon are fitted with lignum-vitæ strips, as the usual practice, and the caps and supporting portions are connected by bolts and nuts, their number and position being shown in the plan.

The cross piece is connected—being a separate detail—to the sides of the frames by bolts and nuts passing through the sides of the cross piece within the length extremities, as shown in the sectional elevation and plan over it. The fittings are the ordinary kind, excepting those for the feathering motion, which of course are additional, and can be easily understood from the two views we have just referred to.

The example that we have referred to has been fitted in Her Majesty's ship *Aurora* of 2355 tons. The engines are 400 nominal horse-power, and the vessel has been on foreign service for the last six years; having had, therefore, ample time and opportunity to test the reliability of the mechanical arrangement as well as the efficiency of the system adopted for the purposes advocated.

As feathering propellers have been constructed of much less dimensions than what we have described, we illustrate an example by Plate 33, which includes an outside elevation and plan of the entire arrangement from the weather deck to the keel.

The hand gear shown above the deck is the same for large as for small screws, so that

the difference in the two examples pertains to the forms of the crosspieces and their connexion with the caps, below, chiefly.

The following Table relates to the ships and their engine power which have been fitted with Feathering Screw-Propellers.

TABLE OF THE PARTICULARS OF THE PATENT FEATHERING PROPELLERS FITTED TO SHIPS, BY MESSRS. MAUDSLAY, SONS, AND FIELD.

Name of Ship.	Nominal Power of the Engines collectively.	Diameter of the Propeller.		Pitch of the Propeller.	
	Horse-power.	Ft.	In.	Ft.	In.
Bosphorus	100	10	0	21	6
Hellespont	100	10	0	21	6
Propontis	100	10	0	21	6
Harbinger	150	12	6	17	0
Queen of the South	300	15	0	17	0
Calcutta	300	15	0	17	0
Lady Jocelyn	300	15	0	17	0
Indiana	300	15	0	17	0
Prince	300	16	6	16	0
Dragon-Fly	12	5	0	5	10
Stork	60	6	0	8	0
Firefly	20	7	0	8	6
Fleur-de-lis	12	5	0	5	10
Nora Creina	28	6	11	10	0
Aurora	400	17	0	17	6 to 22 ft.
Sunbeam	20	7	0	9	6
Hebe	40	8	0	9	0
Argo	300	15	0	17	0

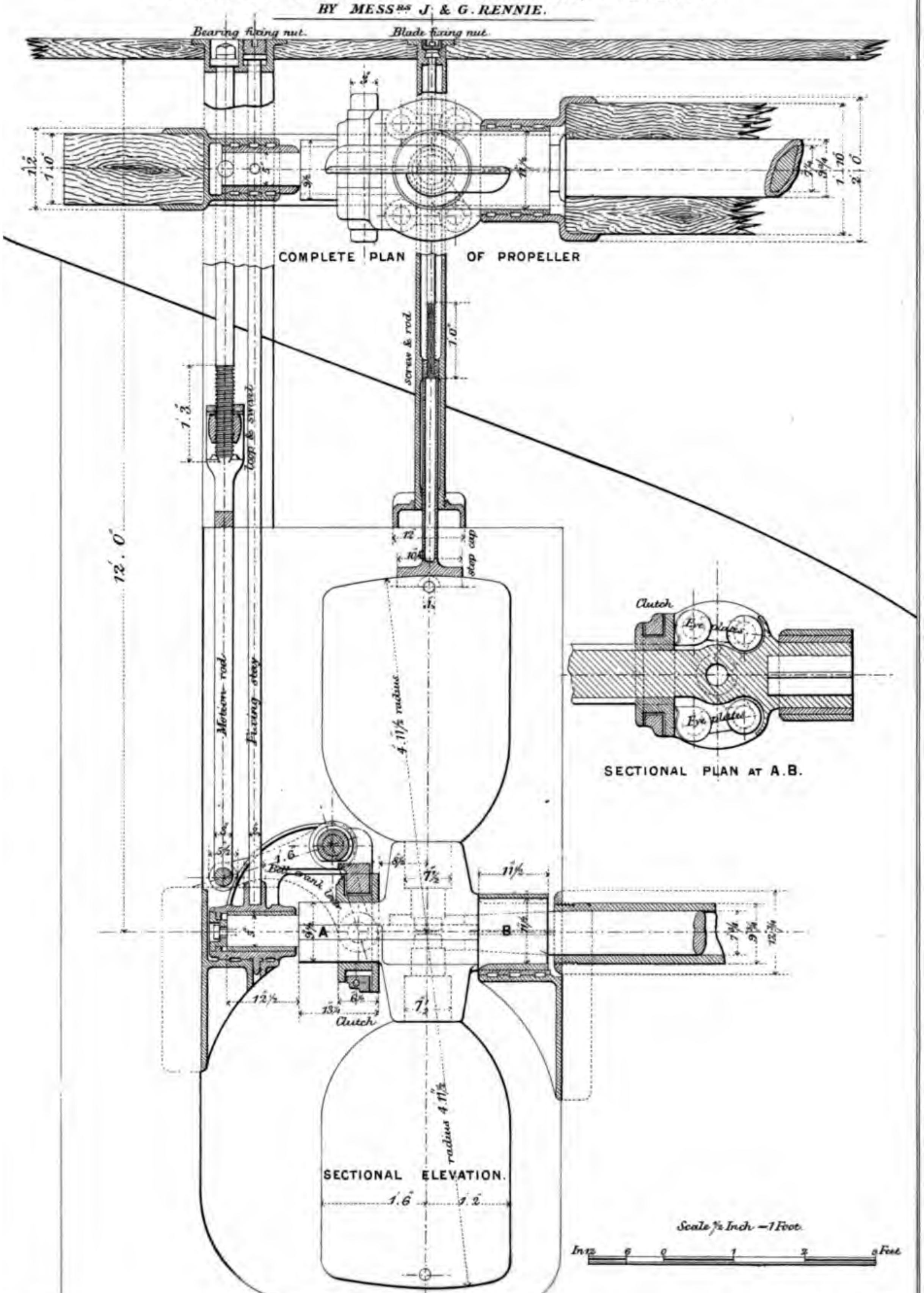
FEATHERING SCREW-PROPELLER—MAUDSLAY'S PATENT—FITTED TO THE AUSTRALIAN STEAM SHIP "VICTORIA," BY MESSRS. J. AND G. RENNIE. PLATE 34.*—This example is the "fixed" type, therefore the "lifting frame" which has been shown in the two preceding plates is in this case omitted. The propeller is of course supported fore and aft by the stern and rudder-post brackets, and the bearings are of gun-metal, suitably arranged for renewal when requisite; this is clearly shown by the sectional elevations.

The details of the "feathering" gear consist of the revolving clutch, sliding disc, eye-plates, blade and crank-levers and motion-rod as for the two other propellers of this kind; and the arrangement of them is nearly the same also; the main difference being in the bell cranks' supporting brackets, which are formed with the aft bearing in this example. There is also a fixing stay directly over this bearing to counteract the lifting action of the levers when they are shifting the blades. The form of the boss of the propeller can be seen from the sectional plan at A B of the elevation; it shows also the eye-plates, clutch, and a portion of the forward bearing.

* By N. P. B.

Plate 34.

FEATHERING SCREW PROPELLER. (*MAUDSLAY'S PATENT.*)
FITTED TO THE AUSTRALIAN STEAM SHIP, VICTORIA.
BY MESS^{RS} J. & G. RENNIE.



Newbery & Alexander lith. 43 Castle St Holborn.

E & F.N Spon, 48, Charing Cross, London.

The "stop clip," to ensure that the blades retain their vertical position when required, is shown in connexion with the blade, also the guide, bracket, screw, rod, and blade-fixing nut.

The loop on the end of the motion-rod and the swivel and screw in connexion, are depicted in section, and as they are so simple we can pass at once to the fixing-nut for the bearing stay contained in a recessed bracket which encloses the extremity of the upper motion rod also.

The complete plan of the propeller illustrates the outline of the feathering gear as far as the clutch only, and beyond this the fore and aft bearings are shown in section, which extends to the side portions of the brackets also, together with parts of the posts to which they are secured.

CHAPTER XV.

A DESCRIPTION OF SEVERAL PROPOSED ARRANGEMENTS FOR FEATHERING THE BLADES OF SCREW-PROPELLERS.

BY N. P. BURGH.

THE purpose of this chapter is a record of various proposals — patented and not patented—that have come under our notice for feathering the blades of screw-propellers, excepting the arrangement by Messrs. Maudslay, Sons, and Field, which that firm has described in the preceding chapter under their name, therefore does not require notice here.

We commence with the description of a proposal that was patented as far back as 1844, by that able veteran in the wars of screw propulsion, Mr. Bennet Woodcroft, which is illustrated at a large scale by Fig. 46, on the next page.

The arrangement first relates to shifting the blades of screw-propellers, which, when required, enable the angle such blades form with the driving-shaft, or axis upon which they are placed, to be changed from a less angle to a greater, or from a greater angle to a less, so that the best pitch of the blades may thereby be obtained for driving the vessel under varying circumstances, such as alterations in the speed of the vessel, in the depth of its immersion in the water, and in the current of water or wind, or of both, in which it is acting. Next, in the combination of apparatus with the blades, by which they are held to any required angle with the driving-shaft upon which they are placed, or are moved from one angle to another, so as thereby to alter their pitch. And, lastly, in the combination of an indicator, with the above-mentioned apparatus and blades, so constructed as at all times to show at what pitch the blades then are, or as nearly so as in practice is required. The nature of this arrangement admits of its being applied to a screw-propeller having any required number of blades, and such blades might be of

then be at a pitch of $7\frac{1}{2}$ ft.; and, provided no slip or recession of the water were to take place by the screw being turned in the water at the rate of 100 revolutions per minute, the screw would in an hour's time have passed through a distance of 8 miles and 90 yards. When the periphery is at the angle shown by the line B, the blades will then be at or nearly at an 11 ft. pitch; and provided they were turned at 100 revolutions per minute, and provided also that no slip or recession of the water were to take place, the screw at that pitch would in an hour's time have passed through a distance of $12\frac{1}{2}$ miles. And when the periphery is at the angle shown by the line C, the blades will then be at or nearly at a $14\frac{1}{2}$ ft. pitch; and if they were turned under the same circumstances as to speed and as to the water as in the two preceding cases, the screw would in an hour's time have passed through a distance of 16 miles and 840 yards.

The side elevation also shows the driving-shaft upon which the screw and the grooved box are placed. This shaft extends from a bearing attached to the false stern-post, and through a stuffing-box in the stern-post to the engine shaft by which it is turned. There is a boss keyed fast upon the driving-shaft, which has four projecting bearings cast upon it, two of which only are seen in this view. These bearings form an angle with the driving-shaft corresponding in some measure with the angle formed by the bottoms of the blades of the screw, which blades they have in part to secure. The outside of each bearing is made in a convex form, with a hole cut through it of sufficient size to admit of the arm attached to the shaft of the blade to pass through it, and to traverse sideways as much as is required to alter the pitch of the blade; and the inside is made with a semicircular slot in it, which, with a corresponding slot in the cap, forms a circular bearing or step for the shaft at the bottom of the blade. When the arm and the propeller blade are put in their places, the cap is bolted to the fixed bearing, and it thereby secures the blade in its working position. The outside of the cap is convex, and is in that respect similar to the outside of the fixed bearing. The grooved box is placed upon the driving-shaft, which shaft has two fixed keys let into it, running in the direction of its length, one on each side. This box is placed over these keys, and it has two slots or key-grooves in the inside, in which the fixed keys on the shaft enter, and by which, when the shaft is turned round, the box is turned round also; but these slots and keys do not prevent the box from being slidden backwards or forwards on the shaft; for on the outside of this box are four oblique grooves which receive the circular heads of the studs. The narrower parts of these studs pass through circular openings; in the end of the arms is a slot passing round the box, into which two studs project which are fixed to the two lower extremities of the bell-crank levers, which levers work upon centres. The pin, which passes through the levers and to which they are keyed, works in a bearing of the bracket which is attached to the stern-post of the vessel. Two links unite the bell-crank levers to

the crosshead. Through this crosshead the motion rod passes, and it is so attached to the crosshead as to turn freely in it, and to move it up and down as required. The upper part of this rod passes through the deck, through a short column fixed thereon —as shown above the side elevation—the part of the rod which passes through this column has a screw on it which works in a nut fixed inside the column. On the top of the rod is fixed a wheel, with handles by which the rod can be turned; also an indicator with a number of teeth placed concentric with its axis on the one side, and having on the other an index plate showing at what pitch the screw is; according to the manipulation of the gear.

Another arrangement of indicator gear is shown at an enlarged scale in section above the bell-crank gear. The guide-piece on the rod has a rack on one side, in which the teeth of the indicator gear. A key is fixed to the column that fits into a groove behind the guide, and also prevents the guide from turning round.

When the wheel at the top of the rod is turned so as to force the rod down, it will, by its action upon the links and bell cranks, force the sliding box on the shaft nearer to the screw, and the oblique grooves in the box acting upon the arms of the screw will turn the blades to a less angle with the axis, and thereby decrease the pitch of the screw; and when the wheel is turned so as to draw the rod up, it will, by its action upon the links and bell cranks, draw the sliding box further from the screw; and the oblique grooves in the box acting upon the arms of the screw will turn the blades to a greater angle with the axis, and thereby increase the pitch of the screw. It will be obvious that when the rod descends or ascends by the screw turning, the box also descends or ascends with it, and the rack upon it thereby moves the indicator over that part of the plate which shows at what pitch the blades of the screw then are.

In the year 1845 a Mr. Christopher Dunkin Hays patented the idea of the arrangement as illustrated on the next page by Fig. 47, which, according to his description, consists in so constructing screw-propellers that the angle of the blades may be altered with facility, and when required the blades may be brought into a direct line with the keel of the vessel, so as not to interfere with the way or steering of the vessel when the propeller is not in use. Also in so constructing and arranging the apparatus that the blades may be removed and replaced, and the propeller unshipped, with facility. The setting of the blades on the same line as that of the keel is of course an advantage when the propeller is applied to sailing vessels, and employed as an auxiliary power only, as it may occasionally be found advisable and economical to dispense with the use of the propeller for a time, and if the blades were not brought into a direct line with the keel, they might materially affect the steering of the vessel, and impede its progress.

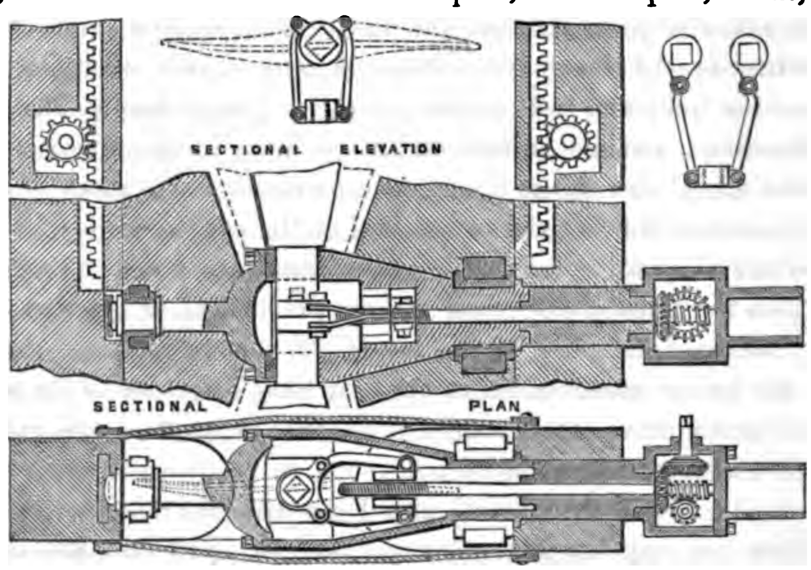
The sectional elevation represents a longitudinal vertical section of a part of the stern of a vessel with a portion of this propeller fitted to it, which includes the apparatus

whereby the angle of the blades of the propeller may be altered or regulated, and the blades brought into a line with the keel.

The sectional plan is a horizontal section taken through the hollow shaft and boss, to which the propeller blades are attached; and also represents part of the stern of a vessel with the propeller applied thereto.

The propeller blades may be either straight or curved, as may be thought most desirable, and the pin stud or axle at their lower end, which is inserted into a hole or socket made in the boss of the shaft for that purpose, is made round or cylindrical. But a portion of the extreme end of these pins or studs are made square, for the purpose of fitting into a pair of sockets connected with the apparatus for altering the angle.

The boss of the propeller shaft is made hollow, as before mentioned, and is of a conical form, as shown in the elevation and plan, and the pins, studs, or axle of the



Mr. Christopher Dunkin Hay's Screw and Gearing arrangement for Feathering the Blades of Screw-propellers. Patented in 1845.

Fig. 47.

propeller blades pass through circular holes made in the conical boss, so as to allow the said blades to turn on their centres when required, but at the same time the conical boss acts as a shoulder or support to the blades, and retains them in their proper position, as will be clearly understood by referring to the elevation. To the outer or larger end of the conical boss a cap-piece is bolted as seen in the two views, and carries a short shaft which forms, in fact, a continuation of the propeller shaft. This shaft is furnished with a movable bearing or step, which rests upon and is supported by a block that is firmly secured to the rudder-post, and fills up the lower half of the vacant space between the propeller-blades and the rudder-post. The inner or smaller end of the hollow conical boss is also furnished with a movable plummer-block or bearing, but of larger dimensions, and also rests upon and is supported by a stationary block, which is

firmly secured to the stern-post and fills up the lower half of the vacant space between the propeller-blades and the stern-post. The hollow conical boss and the short shaft, together with their respective movable bearings or plummer-blocks, are held securely in their places, and kept from moving either vertically or laterally by means of other movable blocks which are let down from above, and by resting upon the conical boss, and the short shaft, effectually prevent them from rising. These blocks, when in their places, are secured by pins or in any convenient manner, and fill up the other half of the vacant spaces between the propeller-blades and the stern and rudder-posts. The inner end of the conical boss is furnished with a clutch, which fits into a corresponding clutch made at the outer end of the propeller-shaft, so that the propeller may easily be disconnected from the shaft, and unshipped, when required.

It will be remembered that the pins or axles of the propeller-blades pass through holes made in the conical boss, but that the lower ends of these pins or axles are made square for the purpose of fitting into sockets. These sockets are enclosed in the hollow conical boss, as shown. The pin of one of the propeller-blades passes through one hole in the conical boss, and its square end is received in the square socket of one of the pieces, and the pin or axle of the other blade passes through another hole made on the opposite side of the conical boss, and is received in the square socket of the other piece. When the blades are to be placed in the proper position, the holes or sockets of the pieces must be brought into coincidence. Then, when the blades are placed in their proper sockets, the end of the pin or axle of one blade will abut against the end of the other, and in order to keep them steady a pin or stud on the end of one of the axles, is made to enter a corresponding hole or socket made in the axle or stud of the other blade. The socket pieces are connected by means of links to a block which is moved backwards and forwards in grooves made in the conical boss by means of the rod which is screwed at one end, and passes through an internal screw made in the block, and has at or near its opposite end a bevel pin in the box. This pinion gears into, and is driven by, a similar pinion, the axle of which passes through the side of the box, and may be turned by a small winch or key.

It will now be understood and clearly seen by reference to the illustration, that upon communicating motion by means of bevel pinions to the shaft, the inner end of which bears against the end of the box, the block will be made to advance or recede along the groove made in the conical boss, according to the direction in which the screwed shaft is turned, and as the block is connected to the socket pieces by the links, the said sockets will be caused to move round, and will thereby turn the blades round on their axes, and consequently alter the angle from which they were originally placed. The detailed view above the elevation, represents the position the block, the link, and the socket pieces would assume when the blades are brought to form nearly a right angle with the keel; and the other view above the gearing illustrates the position

of the several parts when disconnected. Any angle, therefore, between the two limited positions would be a propelling angle, and may be obtained simply by turning the axle of the bevel pinion, as before mentioned; and in order to know the particular angle at which the blades are acting, a graduated dial-plate on the top side of the box, and an index adapted thereto is situated, which is worked in the following manner:—The inner end of the shaft is furnished with a coarse-threaded screw—as seen in the plan—which gears into and drives a small horizontal wheel on the upper end of the shaft or axle, on which an index is affixed. The dial-plate is graduated according to the pitch of the screws at the ends of the shaft, and the number of the teeth in the wheel; so that it will be known by inspection at what angles the blades are, or how many revolutions to impart to the regulating shaft to give a certain angle to them. When the propeller is not in use it may be covered up so as to be completely protected, and to present a more even, regular, and unbroken surface to the run of the water than is presented by the filling pieces. For this purpose the blades of the propeller are brought into the line of the keel, as shown by dotted lines in the plan and elevation, and the propeller and all its apparatus are enclosed as depicted.

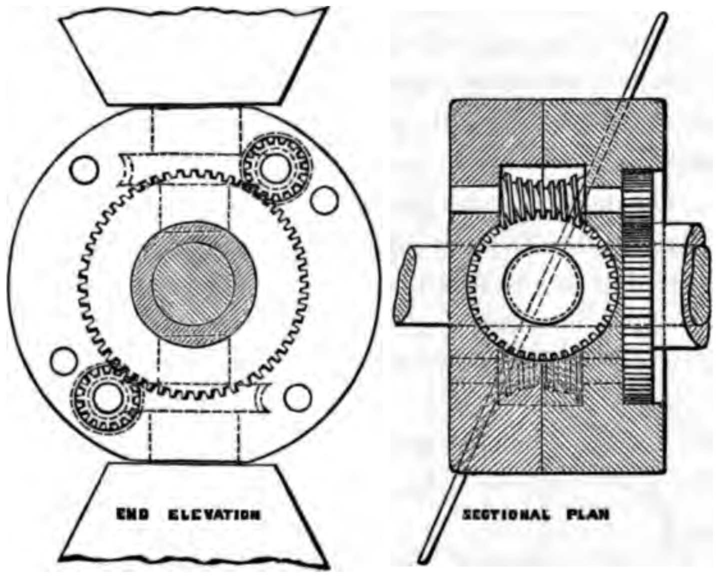
If it is required to unship the propeller, and bring it up on deck, the blades must be made to assume an acute angle with the keel, in order to admit of the filling pieces or blocks being removed; and when the blades are, by means of the shaft and its gearing, brought to the proper angle, the filling pieces or blocks are raised up by turning the pinions which gear into racks made on or attached to the back of the blocks. When these latter have been removed from their grooves it will be necessary to remove the screwed shaft, so as to allow the hollow boss to be disconnected from the clutch of the propeller shaft. In order to do this a short length of the propeller must be removed, as is generally the case in operations of this nature; then the end of the box is taken away, and the bevel pinion and small horizontal wheel is removed, so as to allow the shaft to be unscrewed from the sliding block of the conical boss, and withdrawn from the latter. The propeller with the conical boss and short shaft may then be raised up bodily, and brought on deck through the opening provided—which we add is a complicated means.

Mr. Bennet Woodcroft came forward again in the year 1851 with an arrangement relating to the construction of screw-propeller blades in combination with other apparatus by which such blades may be moved through any or through all the degrees of a circle, whereby the screw may be worked at any pitch, and also whereby an increasing pitched screw may be made to drive a vessel either forward or backward by the concave sides of the blades—when using propellers with increasing pitch, which is preferred—without either stopping or reversing the motion of the engines.

And further, it embraced the construction of screw-propeller blades in combination with other apparatus, by which a vessel may be thereby propelled either forward or backward, or stand still, without either stopping or reversing the motion of the engine.

This is first illustrated by Fig. 48, which represents portions of propeller blades having

ılar axes, on each of which is fixed a worm wheel in gear with a worm pinion or screw d on a shaft on which is fixed also a tooth pinion.



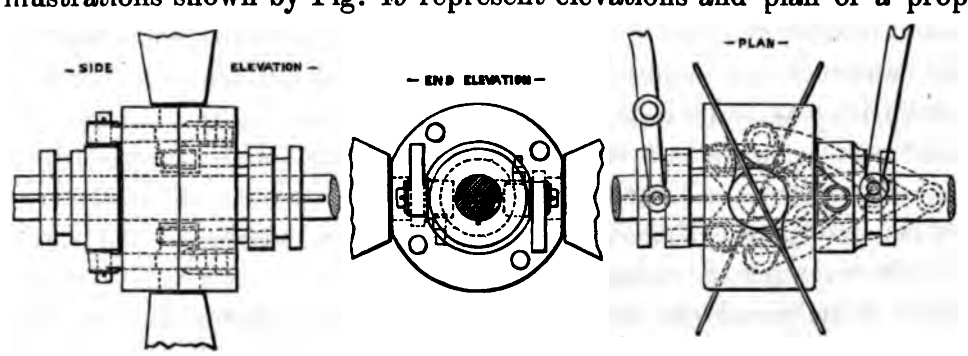
Mr. Bennet Woodcroft's hollow Screw Shaft and Gearing arrangement for Feathering the Blades of Screw-propellers. Patented in 1851.

Fig. 48.

A spur wheel is fixed on the hollow shaft which passes through the stuffing box into ıhip, where it is in gear with wheel work, for changing the direction of motion to ›xtent and at the times when necessary.

The boss of the propeller is made in parts, which is hollow sufficiently to enclose worm wheel, the worm, and the pinion shaft, so as to retain them in any position ired. It will be evident, therefore, that when the hollow shaft is turned around on solid shaft, in either direction, the blades of the propeller may be moved to any ive position accordingly.

The illustrations shown by Fig. 49 represent elevations and plan of a propeller boss

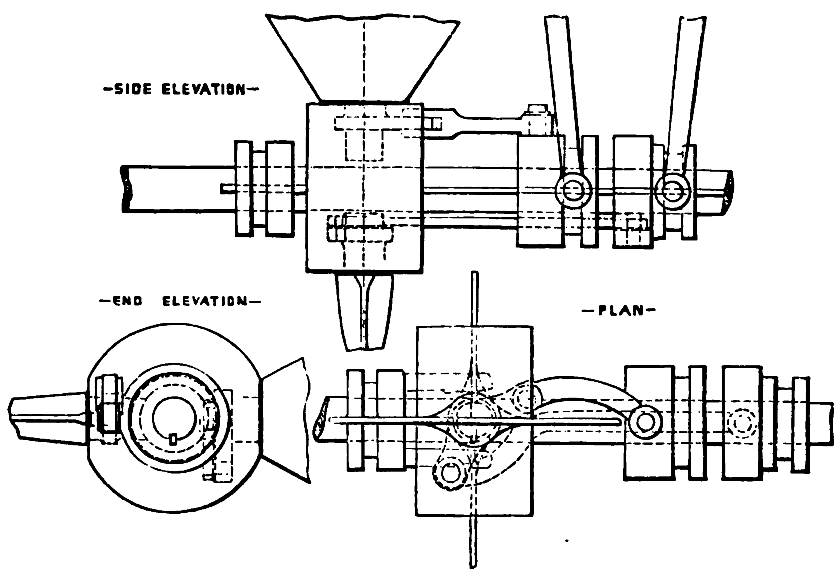


Mr. Bennet Woodcroft's Clutch and Lever arrangement for Feathering the Blades of Screw-propellers. Patented in 1851.

Fig. 49.

and blades with a circular axis passing into a similar opening in the boss, as before. To each axis of the propeller is fixed a short crank, which passes into an opening in the boss, in which it works, and by which it is held in its place. A rod or link is used to move the blades, one end of which is attached by a joint to the crank, and the other by a similar joint to the sliding box. This sliding box, moved by a lever, works back or forward on the propeller shaft, and revolves with it by means of a key-way in the box sliding on a key fixed to the shaft.

The lower end of the motion lever is forked, having two studs, one on each end of the forked part; these studs fit into opposite sides of the groove around the sliding box, as shown in the plan of the blades.



Mr. Bennet Woodcroft's Clutch and Lever arrangement for Feathering the Blades of Screw-propellers. Patented in 1851.

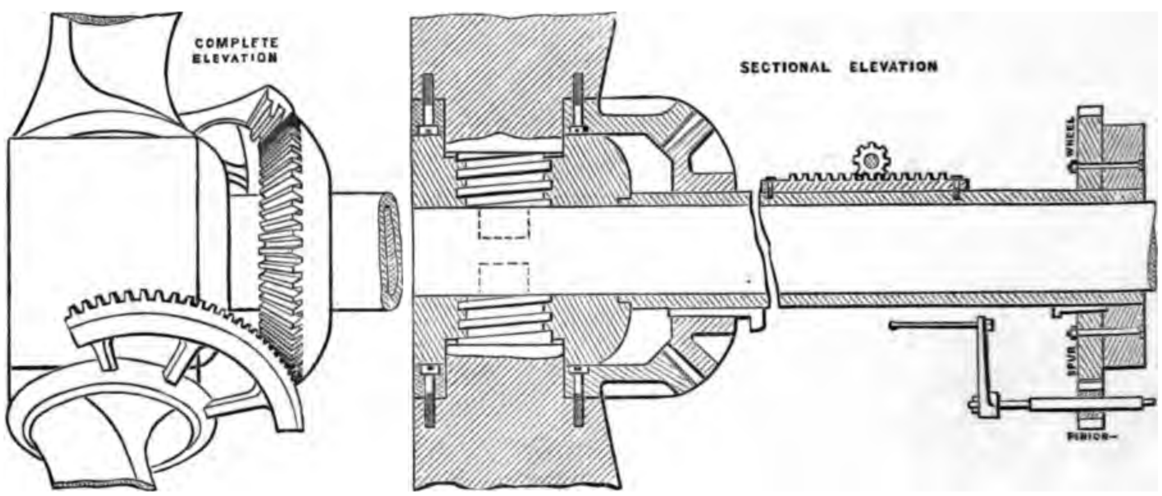
Fig. 50.

A pin or fulcrum is attached to the stern of the ship, on which the lever works; also there is another sliding box opposite, that is constructed and working like the one last described, which is actuated by a lever, as before alluded to.

Attached to the opposite ends of the box are rods which force a break by means of a wedge against the shafts of each of the propeller blades, whereby the latter become fixed to the angle required. It will be obvious, then, that when the breaks or wedges are withdrawn by the lever in connexion, the propeller blades may, by their levers be moved into any of the positions, as shown in the plan, whilst the engine is in motion, and the vessel may thereby be moved forward or backward, or remain stationary.

By the above illustrations, Fig. 50, the propeller is shown as formed in all respects

and the apparatus in combination therewith is similarly constructed to that shown and described in relation to Fig. 51, with the exception of the sliding box being inside of the vessel, and the rods attached to the racks; these rods are recessed into the driving shaft, and those parts which pass into the box have each a projection upon them supporting a friction boss, which passes into the groove inside the box. This box does not revolve with the shaft, but is capable of being moved backward or forward only; and when it is required to drive the vessel either forward or backwards, these friction bosses are confined in the groove by the switches, and the angle of the blades is then varied by moving the box forward or backward; when, however, it is required that the vessel shall move from one side to the other, this box is made fast, and the switches move the friction bosses either into the groove, or one of these grooves moving one of the propeller



Mr. Hewitt's Mitre-gearing arrangement for Feathering the Blades of Screw-propellers. Patented in 1855.
Fig. 53.

blades broadside on it as it passes over the propeller shaft, whilst it is made to pass edgeway on as it passes under the propeller shaft; and the other groove causes each blade to move edgeway on as it passes over the propeller shaft, and broadside on as it passes under the shaft, whereby the vessel is moved laterally in either direction.

After this in 1855, Mr. William Hewitt, a gentleman having a taste for mechanical pursuits, patented an arrangement; and he appropriately commences his description of it with the notice, that it is needless to dwell on the fact that a successful mode for altering the positions of the blades of the screw-propeller, is of considerable importance to navigation. The arrangement proposed by him is illustrated above by Fig. 53, in sectional and complete elevations, where it is shown that on the main shaft of the propeller, there is fitted a boss; or it can be welded thereon if desired, according to the nature of the metal

used; or otherwise constructed, as may be most expedient. Encasing this shaft for a suitable portion of its length is a tube of strength proportionate to withstand the lateral shocks to which the screw-propelling apparatus is always liable. On the end of this tube nearest the stern of the vessel is adjusted and secured a beveled toothed wheel, the teeth of which gear into those of two quadrant-shaped toothed racks that are firmly secured to the blades, in the position as shown in the complete elevation.

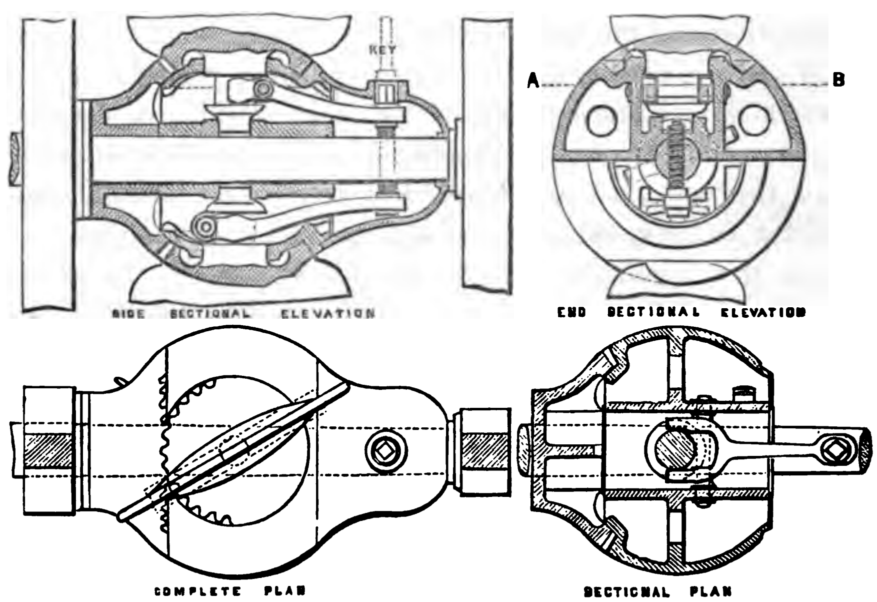
In the sectional view there is shown a straight rack and pinion, the former being fixed to the tube on the shaft. The use of this rack and pinion is to shift the tube forward and backward, and thus put the beveled gearing in and out of gear.

Beyond this is screwed on the tube a clutch and toothed spur wheel in gear with a pinion supported below it. The object of these details is to cause the tube on the shaft to rotate *independently* if desired when the beveled wheel and quadrants are in gear, and thus shift the blades to any required angle, the quadrants being placed on the blades in such manner, as shown in the illustrations, that if they were working in the water little or no resistance would be made; but when the opposite ends of the quadrants commence to gear or work into the wheel, the feathering and consequent impingement on the water and resistance of the latter commences. To effect this propelling power, it is requisite to turn the pinion by a handle, as shown; this imparts motion to the tube or casing, from thence to the bevel wheel, which acts on the quadrant-shaped racks affixed to the screw blades, and by this operation the blades, which are screwed into the boss, are acted upon, and can be moved in either direction, left or right. The screw blades being immersed in the water would render it difficult to ascertain at what angle they might be working at any given time; but to provide against this uncertainty, the clutch is fixed on to the side of the spur wheel attached to the tube, with grooves cut round the face of it, and numbered with the different degrees requisite for the working of the screw blades. A second clutch, not shown, is provided with a tongue across its surface, is made to traverse on the main shaft, and when the blades are feathered or set to the required angle, this clutch is forced forward by means of a lever into the groove it is intended to be fixed, and the shaft being then set in motion, the propelling power is obtained. It may be well to observe that the clutches, racks, and pinions, are all worked from the engine room of the ship, and consequently under the immediate control of the engineer in charge.

Next we direct attention to Mr. Thomas Wingate's proposal for feathering the blades of screw-propellers, in the year 1857, when he started boldly with his description; for he states:

Screw-propellers, made according to this arrangement, while they are easily adjustible to all the angles or working pitches required, are quite as safe and steady in working as the best solid or immovable bladed screws can be. The arrangement is

suited for various forms of screw-propellers, and it is applicable to such as have large central bosses. Each blade is made with a very wide or thick neck, having an end central stud or pin fitting a corresponding hole formed in the boss, whilst the thick part of the neck is faced off to a shoulder with an inclined outer edge or rim, accurately fitting to a corresponding recess turned in the boss. Each neck or shoulder portion carries a toothed bevel wheel or a segment of a wheel, in gear with a central bevel wheel or segment loose on the screw shaft; thus, in a two-bladed screw this gearing consists of three wheels or segments of wheels, the object being to cause both blades to turn upon their axes together when one is turned. In the interior of the large boss there is contained a double lever arrangement, or other suitable movement, connected with an externally



Mr. Wingate's Lever and Gearing arrangement for Feathering the Blades of Screw-propellers. Patented in 1857.

Fig. 54.

projecting screw head, which can be reached from the interior of the ship. When the screw blades are to be shifted, the operator, by means of a key or screwing rod, turns the working screw of the levers within the boss, when the combined action of the two levers then lifts or forces out the two screw blades from their holding recesses in the boss. In this condition the two blades are perfectly free to turn upon their axes to any required working angle. When this is done, a clip on the lower end of a vertical rod which is passed down from the ship's deck above, is made to embrace the outer end of one of the propelling blades. The turning of this clipping rod then obviously turns both blades to the angle required, when both blades are again forced down into their socket-

correspond in form to the exterior of the conical neck. The shank of each propeller blade passes through a central opening in the recessed part of the boss, and the end of the shank is received in a space formed in the metal of the boss where it surrounds the driving shaft. The central part of each shank is turned to form two retaining collars, which receive between them the forked ends of two levers.

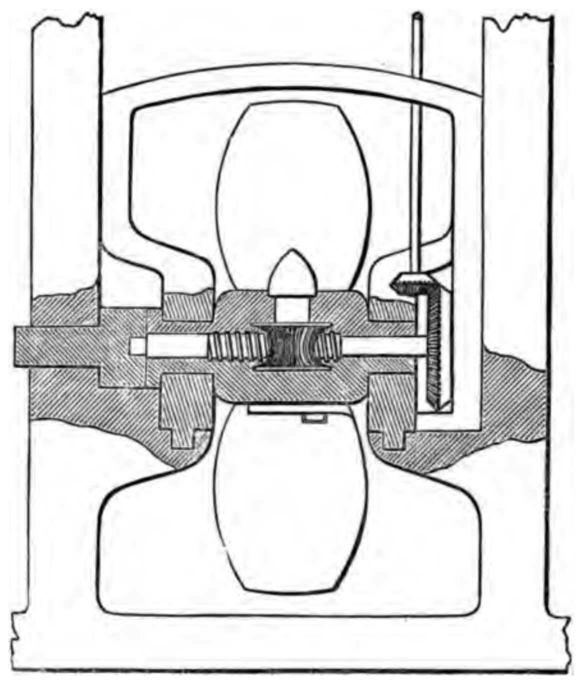
. It will be seen from the elevations that the upper lever is shown as one of the first order, in which its fulcrum is between the power and the resistance or the propeller blade, whilst the lower lever is one of the second order, in which the resistance is between the power and the fulcrum. These two levers are moved in concert, but in opposite directions, by means of a screw, which passes through the driving shaft and is fast to the levers. The forked ends of the levers pass on each side of the central part of the shanks of the screw-propeller blades, as is shown in the sectional plan, which is a section through the dotted line, A B, in the end view. One end of the screw is squared, and comes opposite the conical or funnel-shaped opening made through the part of the boss. A socket-end key is fitted to the squared end of the screw, and this key is of sufficient length to be passed down from the deck of the vessel through apertures, made for the purpose, in the deck and timbers, or plates, of the ship. When the pitch of the screw is to be adjusted or its blades brought into a line with the keel of the vessel, the key is lowered down until its end passes into the opening, and on to the squared end of the screw. The rod of the key is then turned around so as to cause the screw to be screwed downwards. As the screw descends it carries with it the ends of the levers. The mótion of the levers causes the conical parts of the propeller blades to be partially thrust out of the recesses in the boss, in which they were previously wedged. The instant the necks of the propeller blades are free of their seatings in the conical recesses, the blades may be readily turned upon their axes and set to the required angle, or in a plane corresponding with the head of the vessel. The turning of the blades is effected by means of a clip, not shown, which slips over and grips the edge of the upper propeller blade.

In the year 1861 Messrs. Brickhill and Noble proposed an arrangement, which was illustrated in the *Engineer* in the beginning of that year, to set the blades of screw-propellers to any required pitch or angle, according to the power of the engine, or as may otherwise be required.

The illustration, Fig. 55, is a side sectional elevation of this method, which consists of a vertical shaft passing through the deck of the vessel and down to the aft end of the boss of the propeller; this shaft has a horizontal beveled pinion attached thereto, gearing with a vertical beveled wheel, secured to a shaft on which is a worm or screw within the boss. The ends of the blades revolve in the boss, and have affixed to them worm wheels, the teeth of which exactly fit the spaces on the horizontal worm. Thus it is certain that as motion is imparted from the deck to the vertical shaft the blades will be

moved in opposite directions to the pitch or angle required; when the shaft is not required to be used for the purpose it can be raised slightly by means of a screw collar on the deck for the purpose of disengaging the wheels, or throwing them out of gear.

The blades having been set to the required pitch are kept in position, not only by the pressure of the worm wheels on the horizontal screw, but in order also to resist the strain a quadrant is attached to the base of each blade, and secured to the flat sides of the boss by a screw which is loosened or tightened by a spanner or square-ended rod passing through a guide tube in the deck, to ensure its dropping on or into the screw. By



Messrs. Brickhill and Noble's Worm and Pinions arrangement for Feathering the Blades of Screw-propellers, proposed in 1861.
Fig. 55.

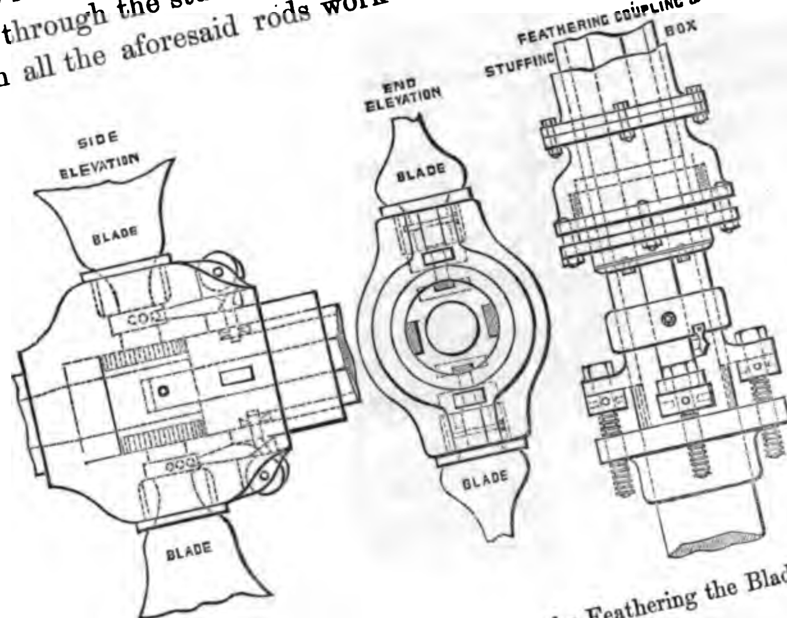
this arrangement the whole screw, with boss, wheels, and bushes, can be raised up by the lifting frame on to the deck for repairs or otherwise.

Mr. Owen an engineer of Manchester, in the year 1862, made public his scheme for feathering the blades of screw-propellers as illustrated by Fig. 56 on the next page, which consisted of the use of rods passing from the propeller through the stern tube, stuffing box, or gland, as desired, and revolving with the screw-propeller shaft, for the purpose of transmitting motion from the engine room, or the end of the screw alley, to the feathering and locking gear within the propeller's boss, which is described as follows:

On the ends of the blade spindles are fixed toothed wheels by which the blades are

made to revolve by the inward and outward motion of the tube fitted on the small part of the shaft, and having in its racks, gearing into the toothed wheels at the ends of the blades. On each blade spindle above the pinions a collar is secured, and in it are two or more holes or recesses, for the purpose of receiving bolts for locking the blades.

Motion is imparted to the tube by the rods, which pass through the stuffing box into the engine room. The locks or bolts that enter the holes or recesses in the collars, take the strain off the feathering gear, and are worked by the levers acted upon by the rods, which also pass through the stuffing box into the engine room or screw alley. The spaces through which all the aforesaid rods work are made water-tight, and the packing



Mr. Owen's Rack and Pinion arrangement for Feathering the Blades of Screw-propellers. Patented in 1862.

Fig. 56.

prevented from being cut or worn by the rods by means of a hoop which enters th box and gland, and revolves with the shaft.

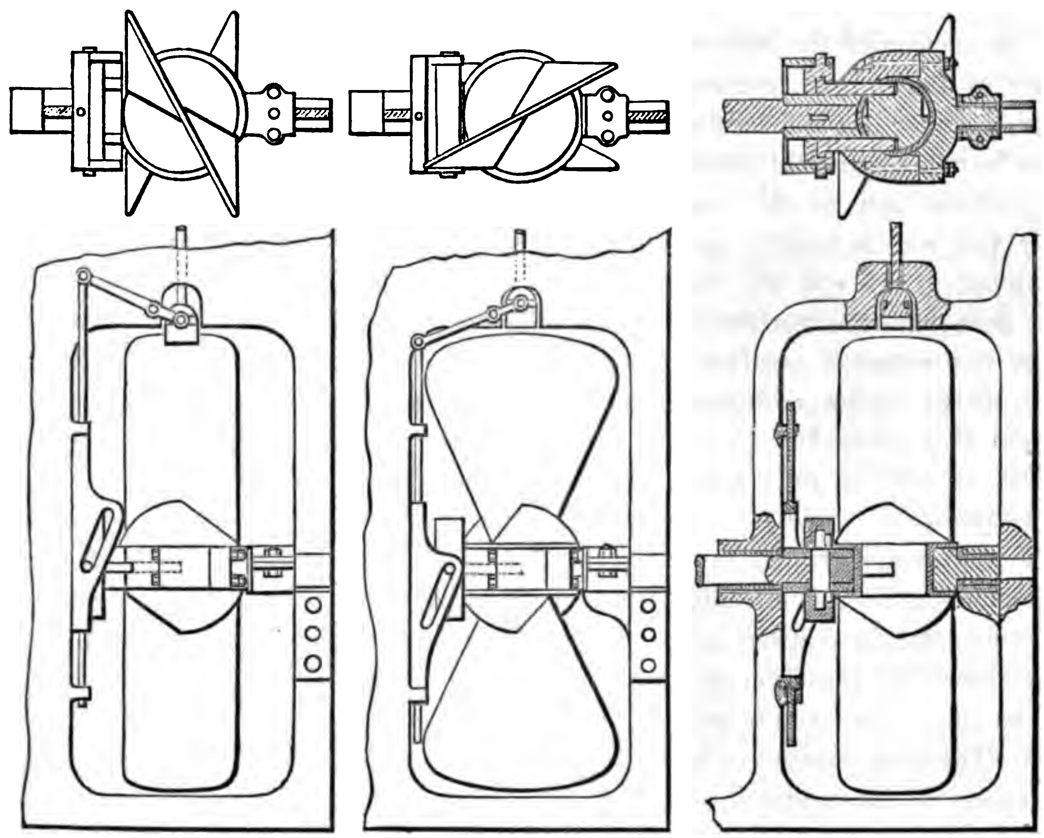
To the propeller shaft is keyed the flange which has in it four screwed for receiving the screws, connected to the rods which work the tube for a pitch of the blades, and two for receiving the screws for working the rods motion to the levers and bolts.

When it is desired to alter the pitch the engines are stopped, the l ns of the screws, and then by turning the screws the l hich is marked on the shaft and indicated by eration is completed.

receive them in a strong wrought-iron or other metal ring. This ring is inserted in the hollow propeller boss, and it is retained in position therein by means of the stem of the propeller blades. Holes are bored in the ring at right angles to the trunnion sockets to receive the stem. The propeller blades are made with a broad flange, in order to bear on a flat surface formed on the hollow boss. A coarse screw is cut on an enlarged portion of the propeller stems, and the boss is suitably tapped to receive the screws. When, therefore, the blades are brought into position, their stems effectually secure the boss to the propeller shaft, leaving, however, the propeller free to turn, as on a hinge joint. Projecting aft from the boss is a trunnion, which has its bearing in a swing frame. This frame, when constructed as shown in the illustration, is covered with wrought-iron plates, and therefore forms a rudder for steering of the ship. To ensure that the propeller turns freely on its compound joint, it is requisite that the centres of the joint-pins of the rudder and of the compound joint should be so arranged as to lie in the same vertical plane. It must be understood that the weight of the propeller and the strain to which it will be subject is sustained entirely by the driving shaft, the trunnion projecting from the rear of the boss acting simply as a guiding arm for changing the position of the propeller blades with respect to the line of progress of the ship; and it will be understood that when the rudder is moved by the steersman the propeller will swing round with it without its rotary motion being affected by the change of position, and that by acting at an angle to the propeller shaft it will materially expedite the operation of steering or manœuvring.

Returning again to the clutch and lever arrangement, we notice next the method by a Mr. Livingstone for feathering the blades of screw-propellers as illustrated by Fig. 58, which is shown by six different views on the next page. The propeller is two-bladed, having the blades and the boss formed together in one casting as seen in the sectional elevation. The boss, instead of being bored out for the reception of the driving shaft, has a circular recess in its centre for the reception of the forward bearing, which is fitted and keyed on the driving shaft, the aft bearing is similarly fitted into the boss, but fastened to it by screw bolts. The inner periphery of the boss bearing is fitted with two half-brass bearings to reduce the friction of the propeller in its bearing; both bearings, with their brasses, when fitted into the groove of the boss and screwed together, will secure the propeller as a strap around an eccentric, and carry it around with the driving shaft, besides allowing the propeller to be turned around its longitudinal axis, as shown in the sectional views. The half bearing has two holes opposite each other, in which two feathers or lock pieces are sliding, which may be moved into corresponding recesses in the boss, whereby the propeller can be locked into its required position, and kept there until the feathers are withdrawn from the recesses. The other ends of the feathers fit loosely into a grooved disc, which disc will remain stationary while the feathers are revolving

with the driving shaft. This disc has on its outer periphery diametrically opposite, two pivots moving in two inclined slots in the frame. The inner width of the frame is a little larger than the diameter of the disc, so as to allow the disc and the feathers to slide into or out of the recesses without causing any friction against the sides of the frame. The inner length of the frame is equal to the diameter of the disc, plus the length of the inclined slots, so that the frame can be raised or lowered for the length of the slots; the



Side Elevation and Plan when the Blades are set at the least Pitch.	Side Elevation and Plan when the Blades are set at the greatest Pitch.	Sectional Elevation and Plan.

Mr. Livingstone's Clutch and Lever arrangement for Feathering the Blades of Screw-propellers. Patented, 1863.

Fig. 58.

consequent action of the inclined slots against the pivots of the disc will be that the feathers will be pushed into the recesses when the frame descends, and withdrawn when the frame rises.

From the deck vertically down through the stern-frame in a line with the longitudinal axis of the propeller when in vertical position, a rod is situated of sufficient

thickness, turning in glands properly packed to prevent the entrance of water. This rod has on its end that projects out of the stern frame a square piece of iron slotted out at the bottom, sufficient deep and wide as to fit into the blade like a spanner, so as to hold it in any position.

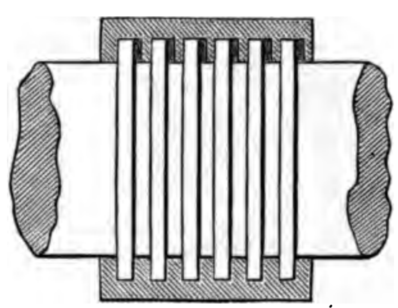
The working of the apparatus will be this:—When the lever is lifted with the rod the spanner will go downward to lay hold of the propeller-blade, at the same time the rod will press one end of the lever down, while the other end with the frame will be lifted up, and the action of the inclined slots against the disc will withdraw the feathers from the recesses in the boss, consequently the propeller will be unlocked at the same time, when the spanner has laid hold of the blade, and merely by altering the vertical motion of the lever into a horizontal position then the propeller will make the required turning on its longitudinal axis in the bearing. This being done, the lever is moved downward, whereby the rod is raised, the spanner loses its hold of the blade, the end of the lever jointed to the rod will rise, the other end with the frame will go down, and the inclined slots push the feathers again into the recesses of the boss, thereby locking the propeller in the required position: the entire arrangement and the two extreme angular positions of the blades are shown by the two complete elevations and plans.

CHAPTER XVI.

DESCRIPTION OF MODERN EXAMPLES OF THRUST-BLOCKS AS FITTED TO SCREW-PROPELLER SHAFTING, BY THE MOST EMINENT MARINE ENGINEERS OF ENGLAND AND SCOTLAND.

By N. P. Burgh.

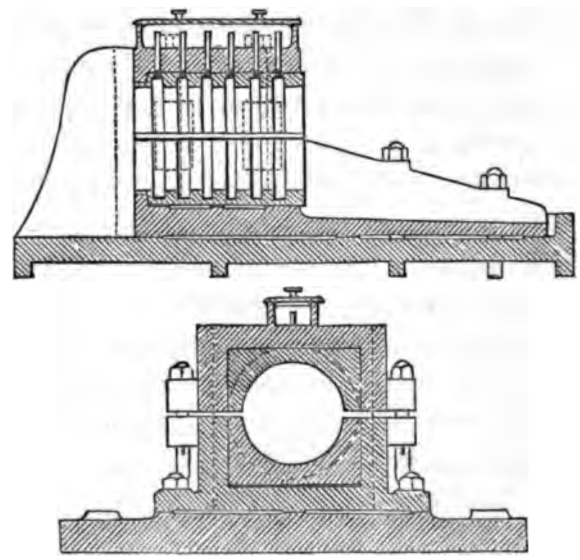
[INT]RODUCTION.—The use of thrust-blocks or plates in connexion with the screw-propeller of course originated when that instrument was adopted as a means of pro[pulsi]on; it being evident [that] as the screw blades [push]ed the ship forward, it [was] pushing the shaft also, [and i]f the latter shifted lon[git]inally, it affected the po[sitio]ns of the engine cranks [and] connecting rods; and if the propeller dragged [the] ship astern, it equally [affec]ted those engine details [ther]efore, unless a similar means of prevention were provided. To produce this, for both cases, the now ordinary grooved thrust-block was introduced, as shown by Fig. 59.



Sectional Elevation of the Ordinary Thrust-Block for Screw-propeller Shafting.
Fig. 59.

This was sometimes fitted with semi-circular strips of lignum-vitæ, as also illustrated, and described by Mr. Penn, in his article contained in Chap. XIII, p. 153. In most cases, however, the practice has been to omit the wood and arrange the [th]e details as shown by Fig. 60 on the next page, which illustrates that the brasses [ar]e adjusted in a vertical direction only, as they are in halves horizontally, and the bolts, and nuts secure them. The lower half of the block is seated on a base plate [which] is secured to the support formed in the hull. The thrust of the propeller is resisted [b]y the ribs above and the projections below the plate, and the key at the aft end of [the b]lock adjusts it longitudinally when required.

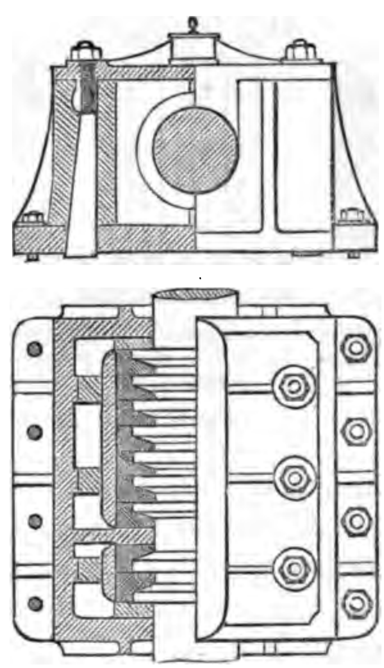
The adjustment of the wearing surfaces of these blocks is of course an important feature in their successful application, and an arrangement for the purpose is illustrated by Fig. 61,* which is the plan and elevation—half in section and complete — of an arrangement that consists of the screw shaft having collars formed on it that are beveled on the thrust sides and straight opposite: within the block is fitted a number of brass blocks corresponding to the spaces between the collars on the shaft, and behind the blocks there are suitably fitted forcing or adjusting plates; at the backs of which there are three screw cotters and nuts, on each side, the use of these being to force the brass blocks against the collars of the shaft when required. It will be seen also that there are packing pieces, fore and aft of the end collars, for the purpose of adjusting the blocks when they are worn sufficiently to fit on to the shaft between the collars; then the packings at the ends are taken out, the blocks are drawn back and thinner packing is substituted; at the same time third and fourth packing pieces are used as required, of a thickness equal to the reduction of the two former, and put in between the blocks next to the intermediate rib; and after this the cotters can be screwed up and the bearing surfaces of the blocks will be again in contact with the collars on the shaft.



Sectional Elevations of an Ordinary Thrust-Block and Base Plate.

Fig. 60.

Of course it will be noticed that the two collars on the forward side of the rib are reverse to those aft of it, and equally obvious that the purpose for this is to resist the aft thrust of the propeller when it is dragging the ship astern; as the seven collars that are all formed alike, receive the thrust for the forward propulsion, and the two collars that are reversely formed, are to receive the thrust for the backward propulsion of the ship.



Elevation and Plan of a proposed arrangement for laterally adjusting the frictional surfaces of Thrust-Blocks.

Fig. 61.

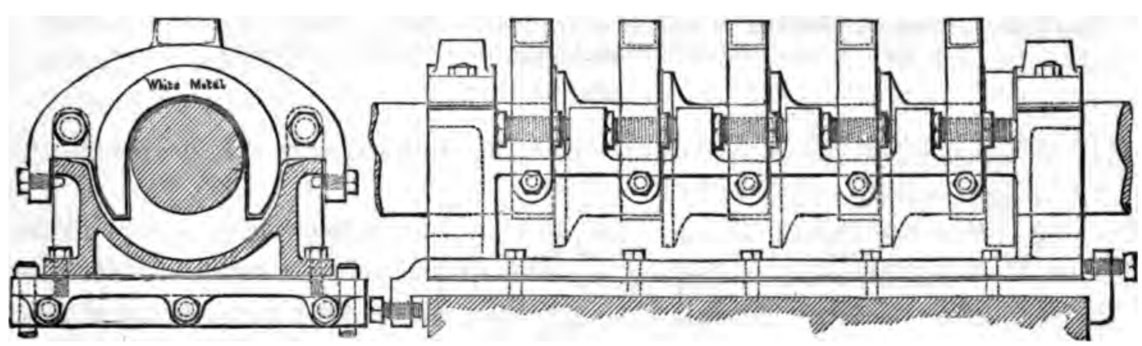
A far better adjustable arrangement has been invented and used with much success by Messrs. Maudslay,

* Appeared in the "Practical Mechanics' Journal," in the year 1854.

Sons, and Field, as illustrated by Fig. 62, which consists of facing the rings on the shaft on the forward side only, and the resistance to the thrust of the screw-propeller is attained by caps being situated against the face of each ring, instead of enclosing them; it will be seen from the sectional view that the frictional surfaces of these caps are shaped much as a " horse's shoe," and they are held down by lateral studs passing under the flanges cast with the casing for that purpose.

As in due time the frictional surfaces require adjustment, it is ensured by each cap being separately fitted with a screwed stud passing through it on each side; and lugs are cast on the casing of the block between which the studs are inserted, so that on turning the studs the caps can be shifted, and locked by the nuts behind them on each stud.

The shaft is supported by two blocks or bearings beyond the adjusting details, fore and aft; and the aft thrust of the propeller is resisted by a ring forged with the shaft acting against the forward side of the aft supporting block.



Side and End Elevations of Messrs. Maudslay's Adjustable Friction-surface Thrust-Block.

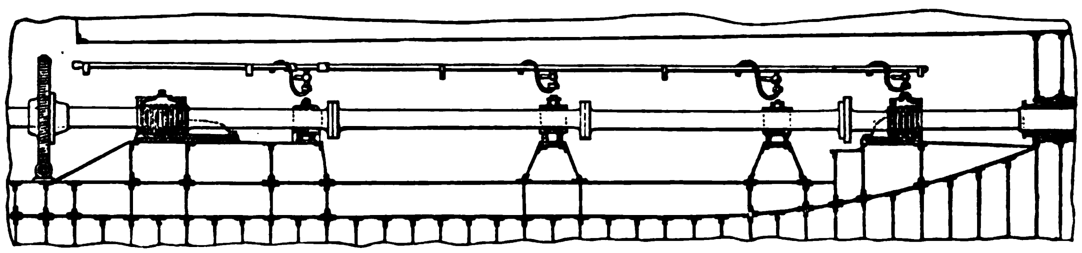
Fig 62.

The casing supporting these details is seated on a base plate that is fitted with three adjusting studs at each end; these studs at the aft end set up or push the casing forward; and those forward, draw the base plate in that direction, and *vice versâ*, it can be shifted when required; so that there is with this entire arrangement a compound means for adjustment; the one portion being unequal adjustment—if desired—or equal if preferred, by the caps and studs; and the other the adjustment of the entire detail or the casing only as most circumstantially practicable.

The lubricating essentialities are also well provided for in this arrangement, by oil cups on the caps, and by the channel below in the casing containing lubricant into which the rings on the shaft revolve and thus take up sufficient liquid to maintain a low temperature of, as well as prevent heated, bearings.

Of course, it is obvious that only two thirds of the area of each ring is in contact with the cap, and therefore the area of the frictional surface is reduced in proportion to

that when the brass encloses the ring; but as the resisting surface in this case is nearly all *above* the centre line of the shaft, it is almost certain that the concentration of the pressure imposed must produce almost equal friction as that occurring with the ordinary arrangement; and more than this, it remains to consider whether the equalised resisting surface is not more effectual than the one now under notice, because the line of the strain being central, it should, properly, be resisted *equally* around that centre. This evidence then being correct, we may safely conclude that the principles of the equal resisting



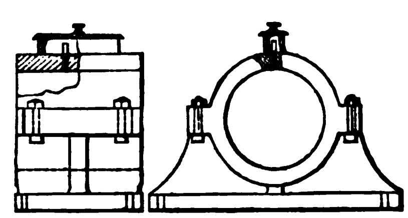
Longitudinal Sectional Elevation of a Screw-alley, Screw-shafting, Thrust-blocks, Support-blocks, Turning Gear, and Lubricating Piping, all of modern construction.

Fig. 63.

surface are sacrificed to the adjusting and lubricating properties in this arrangement; but yet with no practical loss.

It has often been lately the practice of some of the leading engineers to fit *two* thrust-blocks to the same screw shafting in order to maintain its correct position under all circumstances. An arrangement of this kind is shown by Fig. 63, which shows also the fittings complete from the engine-room to the stern tube stuffing box.

The supporting block is usually of cast iron without brasses, soft metal being used in their place as a lining within the bearing part that surrounds the shaft; an example of this class is shown by Fig. 64. This is depicting two elevations of it. A portion of each view being in section to illustrate the oil chamber and pipe. The cap and lower parts are connected by four bolts and nuts, and the base portion is secured by a similar number.



Elevations of Ordinary Screw-shaft Support-block.

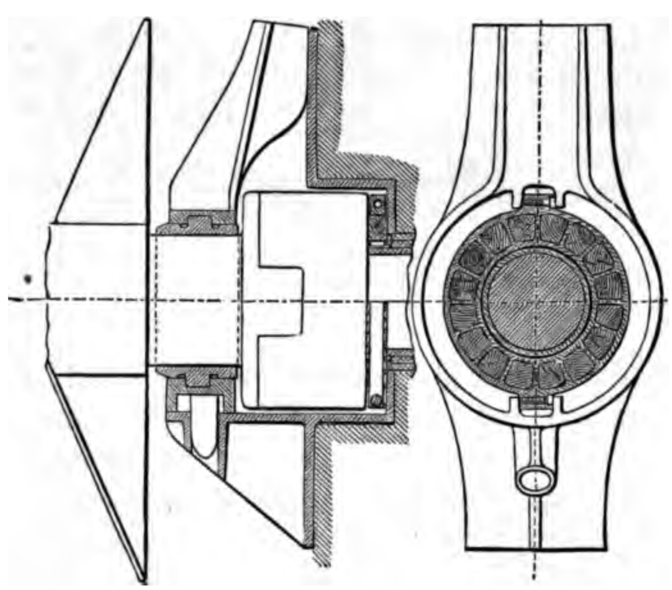
Fig. 64.

Exceptional to the examples of thrust-blocks that we have referred to in this chapter, another mode has been patented by Mr. John Penn, in the year 1857, for resisting the thrust of screw-propellers. For this purpose a disc or plate—by preference made in two parts so as to be readily fixed and removed—is applied between the boss of the propeller and where the propeller shaft passes into the ship or vessel. In this plate or disc are fixed pieces of hard wood at intervals, in such manner, that the pieces of wood somewhat protrude beyond the

surface of the disc or plate. The disc or plate is made suitable for the propeller shaft to revolve freely in an opening through its centre, and it is applied in such manner as to be held from turning around with the propeller shaft. The forward surface of the boss or nave of the propeller, or of a plate fixed thereto, is formed or turned truly, and is, when the propeller is at work, constantly pressed against the projecting surfaces of the wood in the plate or disc, which is, as before mentioned, applied where the propeller shaft passes into the vessel. The thrust of the propeller is thus received by the pieces of wood fixed in the plate or disc, and this being attached to the stern-post of the ship or vessel transmits to it the thrust of the propeller; the plate or disc and wood fixed to it being immersed in the water will be constantly well lubricated therewith.

Although it is preferred to have the pieces of wood applied to a plate or disc capable of being readily removed, this is not essential, and in place of the pieces of wood being applied as above explained they may be applied to the boss of the propeller, or to a plate or disc fixed thereto, or to the propeller shaft, so as to revolve therewith; in which case the pieces of wood, when the propeller is at work, will be pressed against a plate or surface formed or fixed around where the shaft of the propeller passes into the ship or vessel; and although it is preferred that this apparatus should be external of the ship or vessel, a similar apparatus to take the thrust of a propeller may be applied within the ship or vessel, in which case the rubbing surfaces should be kept well lubricated with water.

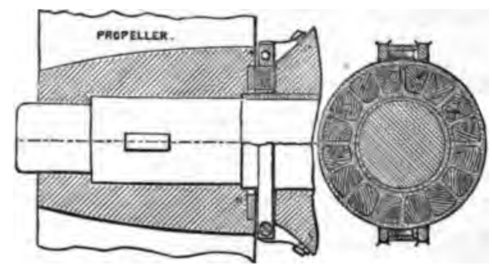
This is all fully illustrated in detail by the following Figs. 65, 66, and 67. Fig. 65 shows part of a longitudinal section of the stern of the vessel and bracket



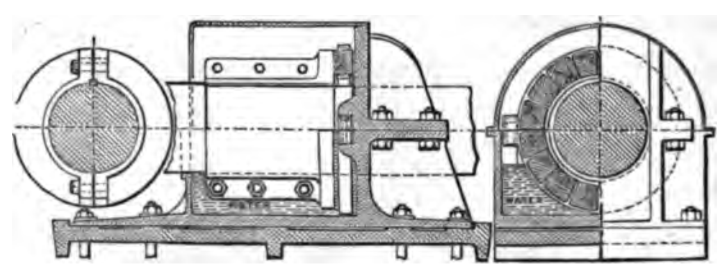
Elevations of the application of Mr. Penn's Patent Disc for resisting the Thrust of *raising* Screw-propellers.

Fig. 65.

arranged suitably for having the screw-propeller to be raised out of the water; and also a transverse section of the thrust disc, screw-shaft, and complete view of the bracket. Fig. 66 shows part of a longitudinal section, and a transverse section of the apparatus, arranged for a fixed screw-propeller; Fig. 67 shows a longitudinal section, and transverse section of the apparatus, when the same is arranged internally of the ship or vessel. When the boss of the screw-propeller is of cast iron, it is preferred to apply or affix thereto a ring of brass such as is shown in the sectional view by Fig. 66, suitable for working against the wood in the part of the apparatus which receives the thrust. The propeller shaft, as shown in Fig. 65, is arranged at its outer end in such manner as to admit of the screw or propeller being separated and lifted, as will be understood from the side view. The disc in all cases is by preference made in two parts capable of joining together, and of being fixed together by screws as shown; this disc or plate has several openings through it, in each of which is fixed a block of hard wood; these blocks of wood somewhat project beyond the surface of the disc; which is prevented from turning with the propeller shaft by means of fixed projections as shown by the end view. In the Fig. 67



Sectional Elevations of the Application of Mr. Penn's Patent Disc for resisting the Thrust of *fixed* Screw-propellers.
Fig. 66.



Sectional Elevations of Mr. Penn's Patent Disc and Apparatus for resisting the Thrust of Screw-propellers, as applied *inside* the hull.*
Fig. 67.

the apparatus is shown to be arranged within the ship or vessel; a trough is formed for containing water, the bottom and also the end of which is made of sufficient strength for resisting the thrust of the propeller. This part of the apparatus is fixed in any convenient position intermediate of the length of the propeller shaft or shafting. In this arrangement the disc is supported by the fixed plate through which the propeller shaft passes; the propeller shaft has affixed to it a brass surface which presses against the blocks of wood. This surface is made in two parts for the convenience of its being affixed to the propeller shaft by screws and nuts as shown, or by other convenient means.

Or, in the place of applying the disc intermediate of the length of the propeller shaft, it may be constructed in a suitable manner for being applied at the forward end of the propeller or crank shaft, and so that such end of the shaft may be resisted by a similar apparatus.

The application of wood for receiving the thrust of screw-propellers, has since the date of Mr. Penn's patent, been successful, as shown by the Plate 21 at page 129, and also by Messrs. Watt and Humphrys, by the Plates 24, 25, and 27, at the pages 136, 138, and 145; the two latter firms using the disc for the astern thrust only.

The application of hydraulic pressure to resist the thrust of screw-propellers, has also been used, by arranging a ring disc on the shaft to act against a volume of water contained in a chamber enclosing the disc and a portion of the shaft. A small pump, put in motion by the shaft, is used to force water into the chamber and maintain a resistance, *against* the disc, exceeding the thrust of the propeller, and a correctly loaded safety valve on the chamber permits the discharge of the overplus water. This arrangement, however theoretically correct as far as non-friction or nearly that, is attained, is not, practically, of sufficient reliant value to warrant its application, on account of the fact, that if the *least* fault occurs in *any* portion of the apparatus, the remainder, although intact, becomes useless for the duty required, which of course, also incurs the stoppage of the propulsion of the ship, during the repair of the "break down," an event common with all complicated arrangements.

CHAPTER XVII.

THE PRINCIPLES AND PRACTICE OF THE USE OF THRUST-BLOCKS FOR RESISTING THE THRUST OF SCREW-PROPELLERS.

BY MR. W. LANGDON.

HAVING been requested by my friend Mr. N. P. Burgh to pen a few lines for insertion in his new work, upon my experience and practice in the construction of pushing-blocks for resisting the thrust of the screw in steam-ships, I feel pleasure in acceding to his request.

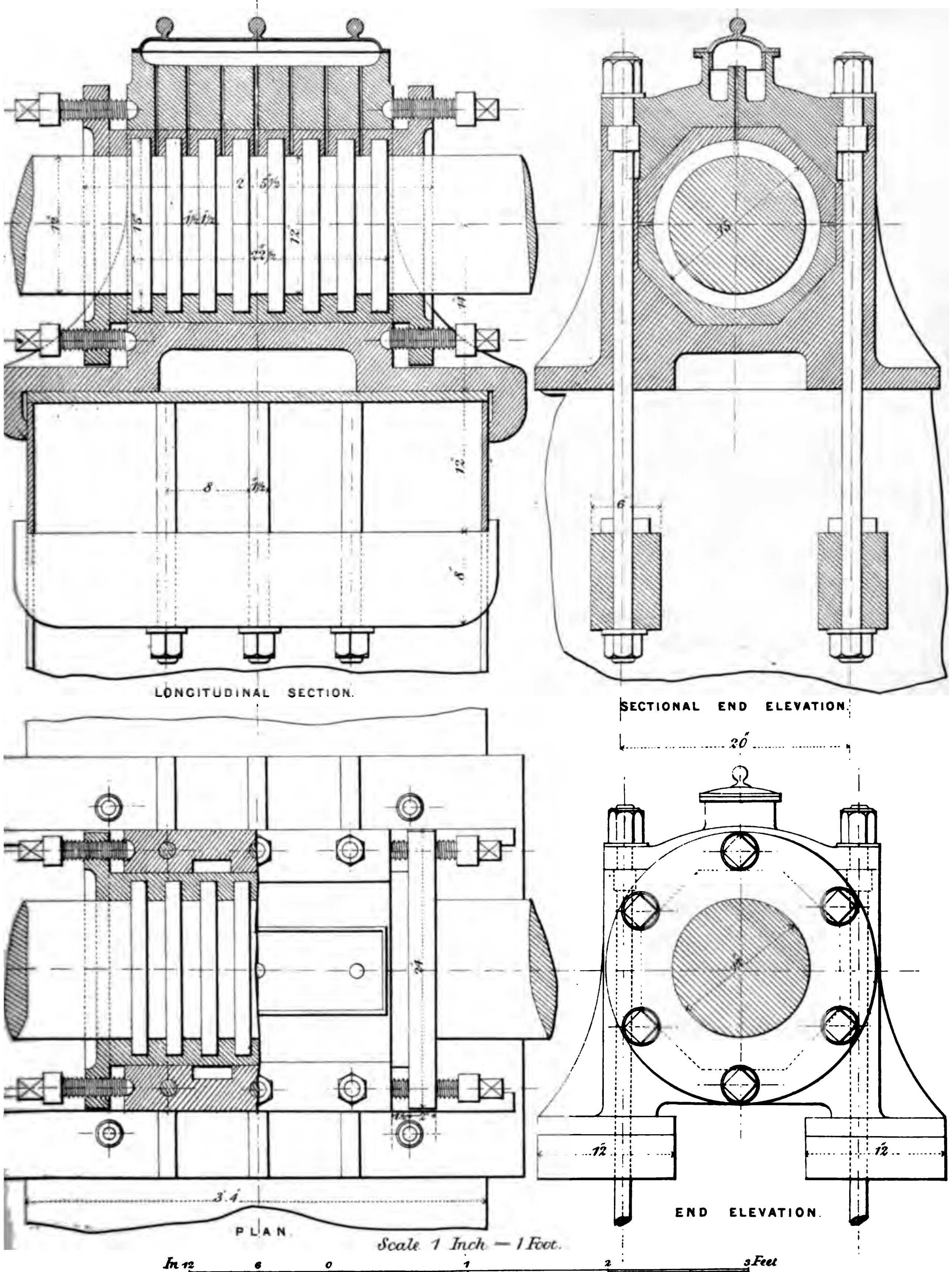
I append a tabular statement, in which I have selected sixteen different ships (out of a far larger number fitted with machinery by Messrs. James Watt and Co.) of various powers and tonnage, and ranging between the years 1845 and 1863, inclusive, which shows at a glance the results of the practice I have followed.

I disclaim invention of any sort. Of the three methods referred to in the Table, firstly, by annular loose rings rubbing upon each other; secondly, by the thrust upon the end of the shaft; and thirdly, by the fixed collars *forged* upon the shaft, were known generally, the latter, and certainly by far the best, I believe to have been first introduced by some one at Glasgow.

Taking the *Eurotas*, in 1845, it will be observed that the surface employed was very large; this was done purposely, the annular ring system not being nearly so efficient as the fixed collars. I cannot give the result, as these engines were not erected on board the *Eurotas*, but were placed in another ship several years later, when a different plan was adopted.

In the *Thames* and *Elbe*, the *Free Trade* and the *Eider*, 1847, the thrust was taken upon the end of the shaft, pressing upon a steel plate, made as hard as possible, and immersed in a bath of oil and water, provision being made for the constant change of the latter. This did tolerably well; but constant care and attention was required to prevent

THRUST-BLOCK FITTED TO S.S. "JASON" BY MESSRS J. WATT & Co



Newbery & Alexander lith. 43 Castle St Holborn
E & F N. Spon. 48. Charing Cross London

fusion, and the plan soon gave place to the collars, or rings forged upon the shaft, now in general use, and so efficient as not, in my opinion, to require further improvement.

In the Table before referred to, I have given sufficient detail to enable any one to calculate in his own way what may have been the thrust of the screw in lbs. on the square inch, which has been determined in many cases by the dynamometer. As a matter of practice, I believe that ·75 square inch of collar surface to each indicator horse-power is sufficient and safe, requiring ordinary attention only from the engineer. For years past thrust blocks have ceased to give me the slightest anxiety when at sea, or upon a trial of new engines at the measured mile.

On board the *Jason* (1853) I introduced set pins at each end of the block, by which the brass could be adjusted with great accuracy. I have followed this plan since then. A drawing of the block is shown by the Plate H.

These rings or collars may be employed with advantage in paddle-wheels. In 1858, when designing those for the *Ulster* and *Munster*, Irish mail packets, two of these collars were introduced in each paddle block, thus removing all pressure from the bearings of the engine entablature, and confining it to the strongest part of the ship. These wheels had a polygon of 29 ft., were 33 ft. diameter over the floats, and each wheel weighed over 70 tons; it was, therefore, essential that they should be carefully secured, taking into consideration the heavy duty these vessels have to perform. It may be interesting to note that these wheels were fitted with lignum-vitæ bearings, working upon brass pins, perhaps a very early introduction of the plan. The chief merit of it appears to consist in the fact that there is little or no wear upon them, and the small amount of friction in working is remarkable. For the introduction of wood bearings to screw shafts the world owes a debt of gratitude to Mr. Penn. I say "screw shafts," otherwise the plan was not new, for when serving part of my apprenticeship at Soho, in 1830, wood bearings were used in part of the ordinary lathe shafting; they were of beech, and were lubricated by oil.

Messrs. Maudslay have designed and used a peculiar kind of pushing piece. I have seen many of them at work; they answer perfectly, taking the pressure on the upper moiety of the periphery of the collars. In the block I have used, it is taken upon the whole circle, the centre of resistance being in the centre of the line of shafting. I do not think this is of importance either way, the rigidity of the shaft being so much beyond what is required of it for pushing purposes.

In conclusion, I may say however that I *do* claim the introduction of the solid coupling ends to screw shafts, as shown in this book, by Plate 21, at page 129.

In the *Verbano*, in 1852, the shafts were so made, by my friend Mr. Hardy, at the Thames Iron Works, who at first pronounced it to be impossible; however, he soon got over the difficulty, and immediately a set of 12-inch shafts were ordered for the *Jason*. Had this plan been patented, I apprehend it would have proved as profitable to us as the

famous patent, for the use of wood bearings, of my friend Mr. Penn has been to him. Drawings of both these sets of shafts are shown by the Plate I.

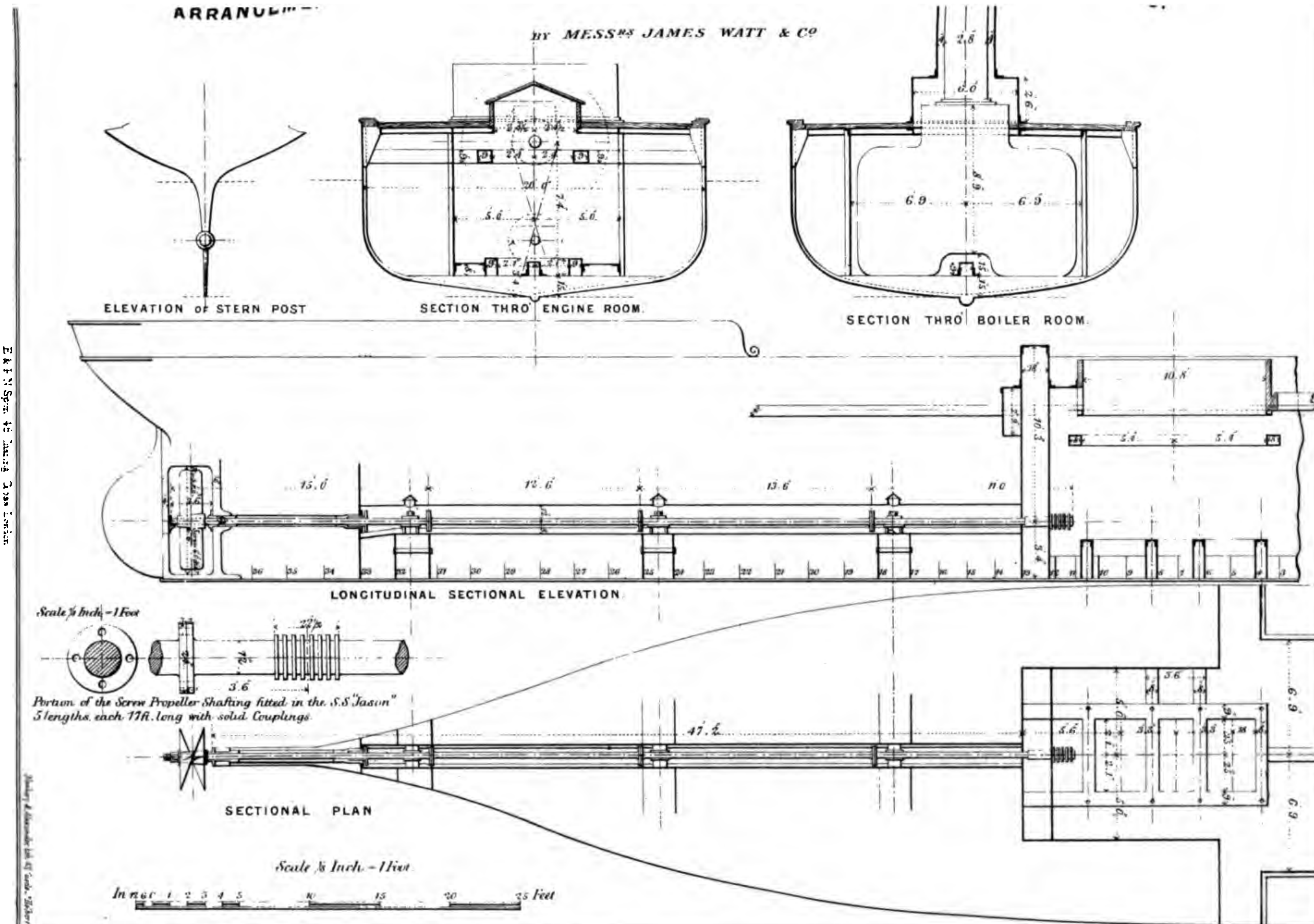
Name of Ship.	Date.	Number and Diameter of the cylinders.	Length of the stroke of the piston.		Nominal power.	Diameter, pitch, and length of screw.					Collars minor and major diameters.		Number of faces in collars.	Total Area of collars in square inches.	Square inches Area per nominal horse power.	Square inches Area per indicated horse.		Indicated horse power.	Description of engine.	Remarks.
		In.	Ft.	In.		Ft.	In.	Ft.	In.	In.	In.	In.			'					
Eurotas	1845	4 of 44	2	6	350	12	0	16	6	30	16	24	Seven.	1759·	5·02	2·34	A.	750	Direct.	Rings not trie
James Watt ...	1846 / 1852	4 of 58	3	0	700	17	0	25	0	36	12½	15½	Ten.	659·	·94	0·26	...	1700	Do.	Admiralty screw.
Thames & Elbe.	1847	2 of 27	2	6	40	7	3	8	0	17	End of top shaft in water.		...	12·5	·31	0·15	B.	85	Oscillating gear.	Two bladed, Smith.
Free Trade, &c.	1847	2 of 31½	3	0	60	8	3	9	0	18	0	5	...	19·63	·327	0·15	B.	130	Do.	Do.
Verbano	1852	2 of 32	2	6	60	6	0	8	6	17	5	7	Six.	113·1	1·885	0·14	...	160	Do.	Do.
Mauritius	1852	2 of 55	3	0	300	15	6	27	0	63	8	15½	Eight.	1107·4	3·69	0·17	...	650	Do.	Maudslay,
Industry	1853	2 of 36½	3	0	80	10	0	11	6	24	6	8	Six.	132·	1·65	0·45	...	288	Direct.	swiveller
Tumbes	1853	2 of 37	3	0	100	9	0	14	0	24	6	8	Seven.	154·	1·54	0·53	..	290	Oscillating gear.	
Jason	1853	2 of 64	3	0	400	16	6	26	0	36	12	15	Eight.	509·	1·27	0·56	...	900	Direct.	First screws to
Sans Pariel......	1853	2 of 64	3	0	400	16	0	16	0	32	8	15½	Eight.	1107·4	2·767	1·10	...	1000	Do.	pushing brass.
Hornet	1853	2 of 38	2	0	100	10	0	13	6	24	8	10½	Six.	218·	2·18	0·94	...	233	Do.	
Ville de Paris*..	1856	2 of 32½	2	6	80	6	0	10	0	18	5	7	Seven.	132·	1·65	0·78	...	170	Oscillating gear.	Three bladed.
Great Eastern...	1856	4 of 84	4	0	1600	24	0	44	0	39	22	28	Ten.	2356·	1·47	0·49	C.	4800	Direct.	
Artelshick	1857	2 of 32	2	6	60	9	6	10	0	20	6	8	Seven.	154·	2·566	1·02	...	150	Oscillating gear.	Four blades.
Prince Regent...	1862	2 of 71	3	0	500	18	0	23	0	32	12	15½	Twelve.	907·	1·81	0·86	...	1050	Direct.	Griffiths.
Hellenis	1863	2 of 44	2	6	120	11	9	15	0	27	8	10½	Eight.	290·	2·41	1·06	..	237	Oscillating gear.	Three blade

* Ville de Londres, La Manche, La Seine, and La Tamise, five in all.

A. There were a series of rings pressing upon each other, with adjusting screws attached to the main mast, the lower portion being of wrought iron, with a large hole in it for the passage of the shaft. These engines were not erected on board the *Eurotas*.

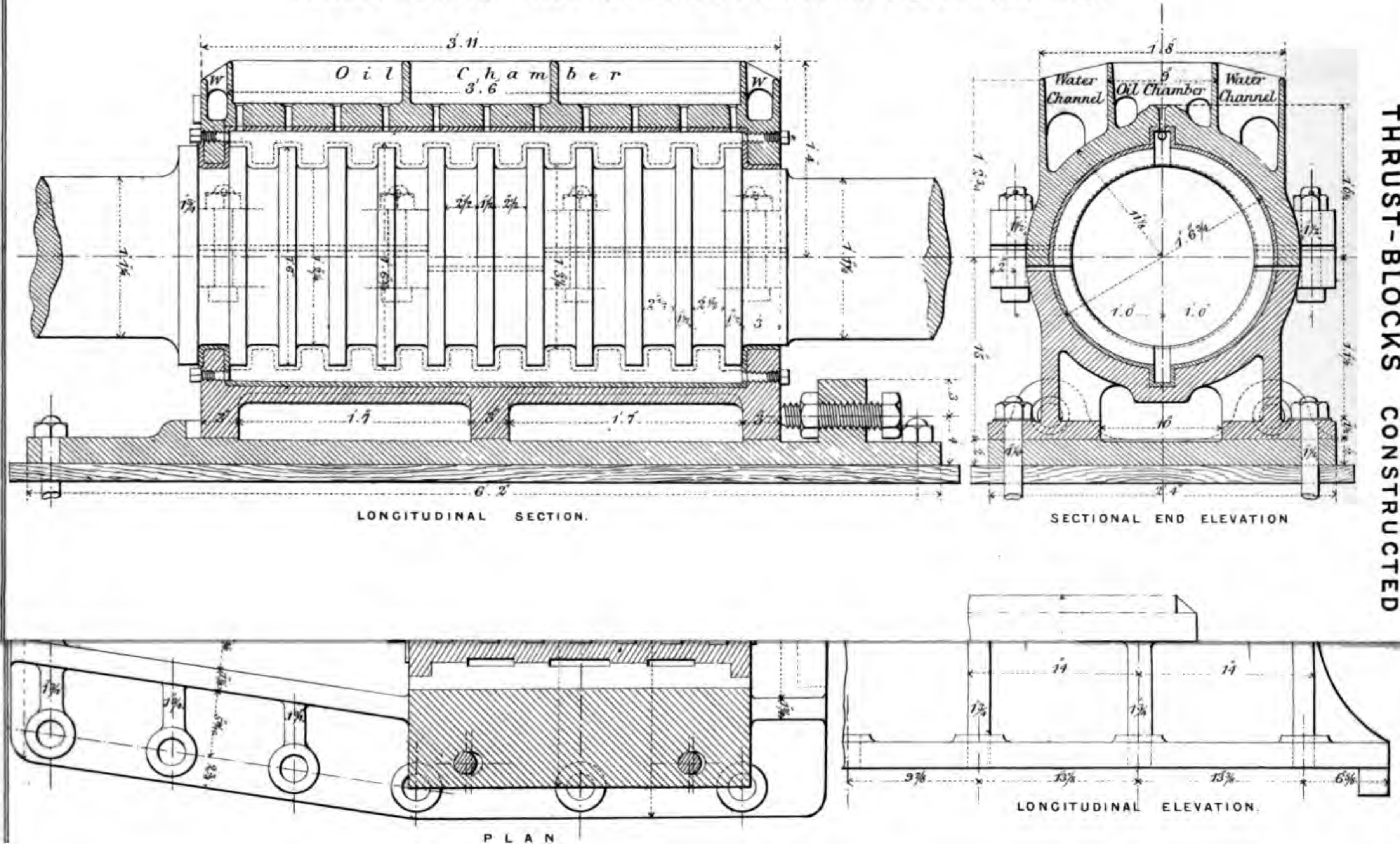
BB. The thrust was taken from the end of the shaft upon a steel plate, working in oil and water.

C. This was very efficient, no trouble of any kind taking place.



E & F N Spon 48 Charing Cross London

"THRUST-BLOCK" FITTED TO S.S. "MOOLTAN" BY MESSRS. DAY & Co.



THRUST-BLOCKS CONSTRUCTED

Plat

CHAPTER XVIII.

A DESCRIPTION OF MODERN EXAMPLES OF THRUST-BLOCKS AS FITTED TO SCREW-PROPELLER SHAFTING, BY THE MOST EMINENT MARINE ENGINEERS OF ENGLAND AND SCOTLAND.

BY N. P. BURGH.

THRUST-BLOCKS CONSTRUCTED BY MESSRS. DAY AND CO. AND BY MESSRS. LAIRD, PLATE 35.—The arrangement by Messrs. Day has lately been fitted into the steamship *Tooltan*, engined 450 horse-power nominal. This block is shown by sectional elevations; plan half in section and half complete; and half side elevation. The side sectional levation illustrates that the shaft has *twelve* rings on it, and that it is supported on a casing f *white-metal* in the place of brasses and that metal combined, as the general practice by any of the leading firms. This casing surrounds the shaft only at the extremities of the lock, or in front of the forward ring and between the two aft rings: between these limits here is a channel in the casing over and under the shaft, the width of which is shown in he end sectional elevation, where it is seen also that the casing is in halves, and is suitably tted to the cast-iron cap and seat of the block. The oil chamber in the cap is centrally tuated, and is surrounded by a water channel: the lubricant from the chamber passes to the top channel in the casing through the eleven holes formed in the cap; and as the haft turns around it is carried into the lower channel, so that the shaft is lubricated at wo parts at the same time.

The casing is secured to the cap and seating by two studs at each end, situated over nd under the shaft. The outline of the cap and seating are uniform, and the base late is fitted with two adjusting studs and lock nuts at the forward end and a set key t the aft end, for adjusting the block and the face surfaces of the casing, of white metal, o the rings on the shaft, for as the casing is secured in the block, it is requisite to shift the latter to move the former. The half side elevation shows that a portion of

the cap is recessed into the seating, and thus any longitudinal shifting of the cap is prevented.

The plan that is half in section and half complete, depicts the number and position of the cap-bolts, also the number of the block-securing bolts and the holding-down bolts for the base plate; both the channels and chamber in the cap, it will be seen, are ribbed, and in the end sectional view that these ribs are hollow at their basis for the lubricants to pass through; as all the leading portions are fully dimensioned in this plate, we will not comment yet on their proportions, but pass at once to the thrust-block illustrated below, constructed by Messrs. Laird.

The arrangement of Messrs. Laird's thrust-block illustrated in this plate differs entirely from that just described, and it is worthy of notice also that this shaft has only eight rings on it, although it is but 1¼ in. smaller in diameter than the other by Messrs. Day.

The shaft is supported in brasses that are bored to suit it, and are fitted to the seating and cap uniformly with a flange at each end to obviate any longitudinal movement, and the lower brass is recessed into the seating centrally to prevent any circular shifting.

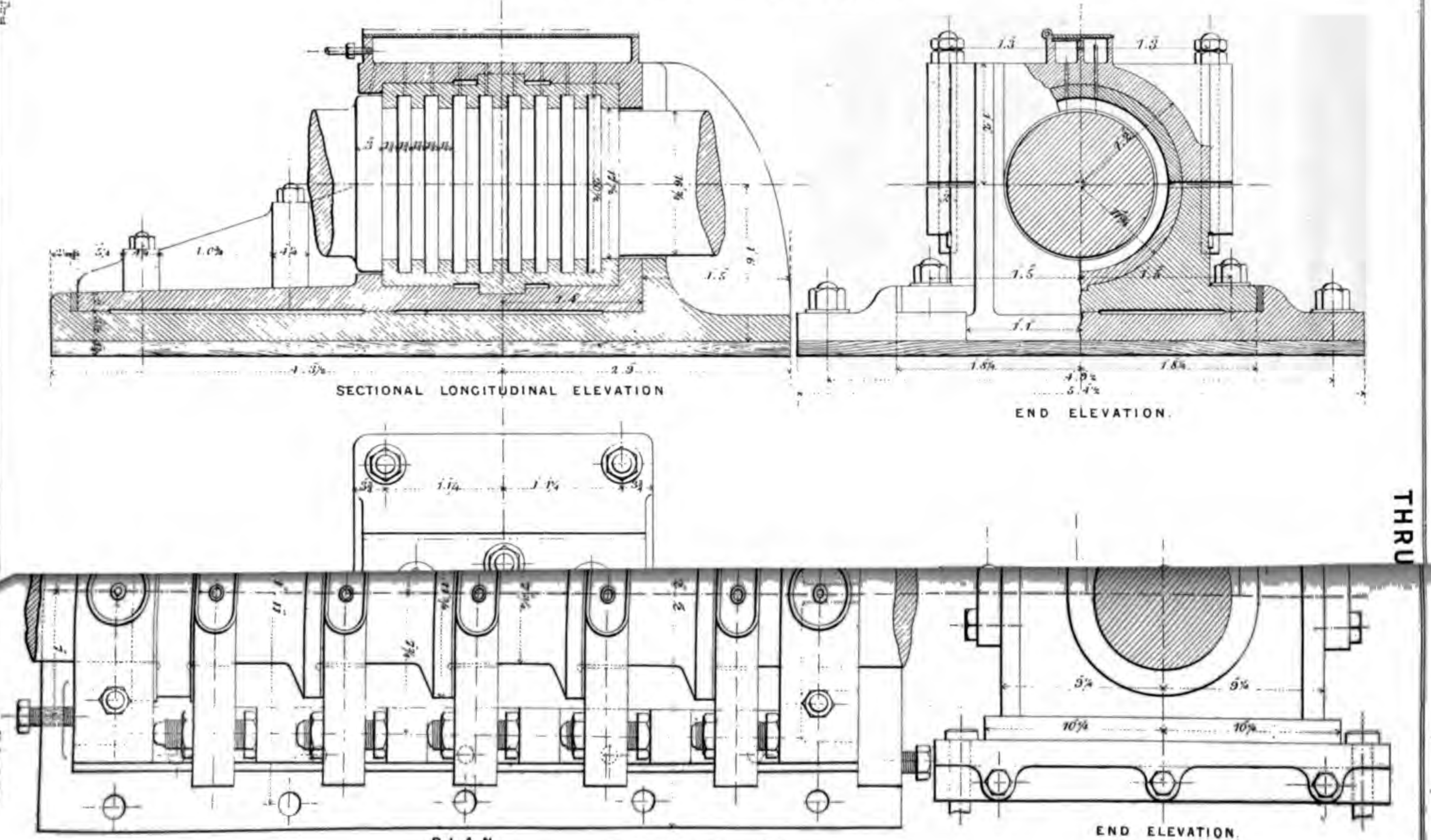
The connexion of the cap with the seating is unlike that preceding, as in this case the cap is recessed into the seating instead of the central flat connexion, and the portion recessed encloses the upper brass. The oil chamber and water channel in the cap are side by side instead of the latter surrounding the former; and the longitudinal section of the water channel is shown in the side sectional elevation; the transverse sections of both being shown in the end sectional elevation; each lubricant passes through seven holes in the top brass, and thus when required, both can be used at the same time, or separately, which latter is the general method; it may be added that the face of the aft ring is lubricated with oil only by an additional tube for that purpose only.

The forms of the channel and the chamber are different from each other, as will be seen from both the sections alluded to, the former extending directly to the brass central of its width and length for certain spaces, and the latter being entirely separated from the brass by the metal forming the cap.

The connexion of the seating and base plate is peculiar, as the seating is recessed into, or put between, projections that are formed on the base-plate, as seen in the end sectional elevation; the flange connexion of these two portions is recessed also, the projections being on the seating and the spaces in the base plate, as shown by the complete side elevation. The cap flange connexion, it will be seen from this view, is recessed in an opposite direction to that below it, but the advantage of the prevention of longitudinal disturbance is of course the same with each, as is the relieving of the securing bolts from any shearing strain.

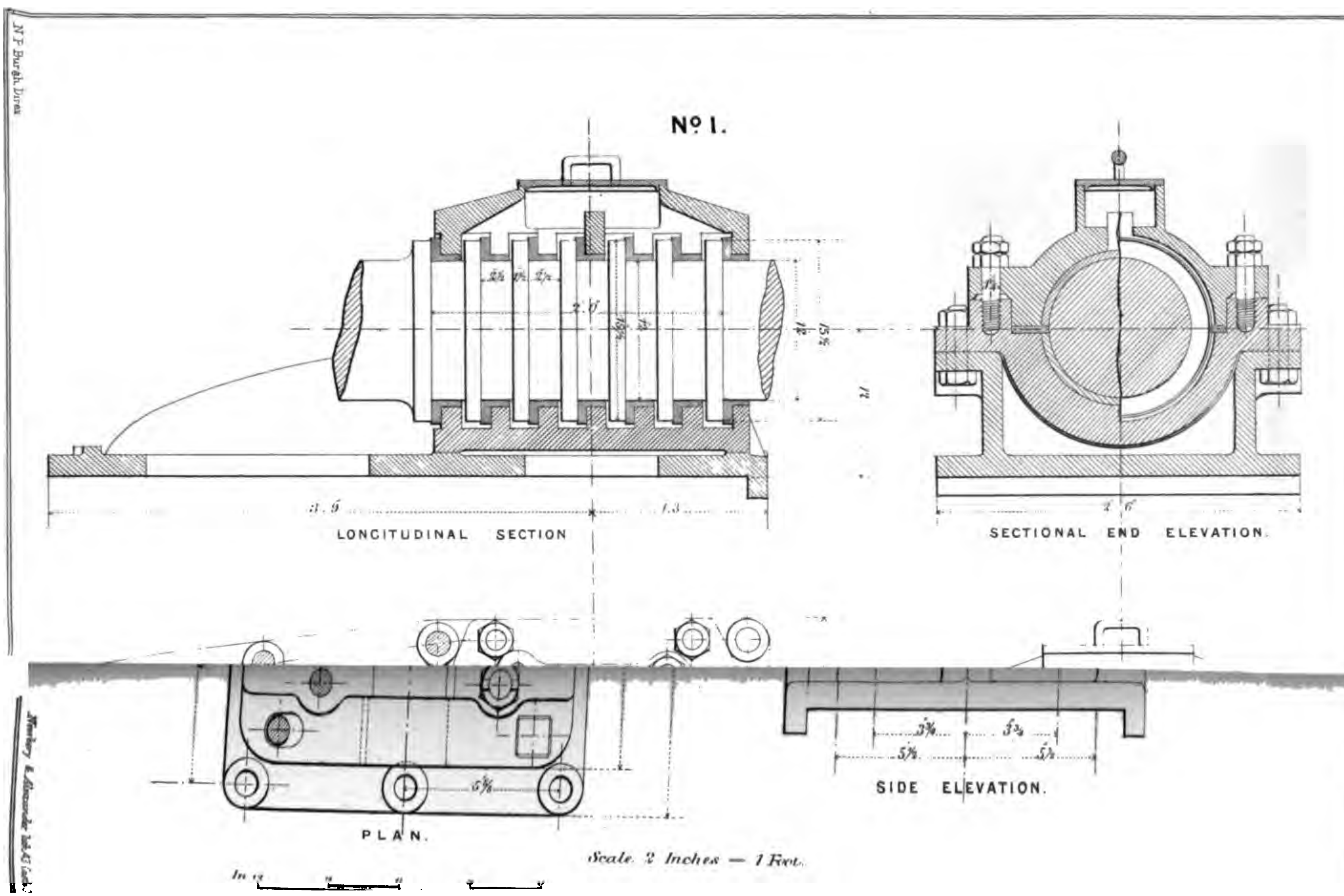
The flange connexion of the seating is fitted with keys, situated at the aft ends of the

MESSRS. PENN'S THRUST-BLOCK.



Scale 1½ Inch = 1 Foot.

Nº 1.


N P Burgh Direx
LONGITUDINAL SECTION
SECTIONAL END ELEVATION.
SIDE ELEVATION.
PLAN.
Scale 2 Inches — 1 Foot.
Newbery & Alexander lith.

recesses which are used to adjust the block, and therefore adjust the brass faces against the rings on the shafts, in the place of set studs, as in the example above in the plate.

The plan is a complete view, and shows the outline of the cap block and base plate, also the number of the securing studs and bolts for the two sets of flanges, with the position and number of the holding-down bolts of the base plate. This plate, it will be noticed, extends at the aft end for some distance beyond the block, and is there ribbed on each side of the shaft.

THRUST-BLOCKS CONSTRUCTED BY MESSRS. RAVENHILL AND HODGSON, PLATE 36.—The example designated No. 1 in this plate is arranged very similar to that shown in Plate 35, and just described, as constructed by Messrs. Laird; indeed, so far does the resemblance extend, that we shall confine our present remarks to the portions that differ from that only. The brasses in this case do not surround the entire portion of the shaft within the block; but are formed to fit around the parts between the rings and against the faces of them, as shown in the side sectional elevation and plan. The thin brasses opposite the thicker in the latter view, are the portions that are fitted against the shaft where the larger brasses are divided at the centre line, to prevent oxidation occurring from the use of water lubrication, as well as the rusting of the wrought iron in contact. It will be noticed in the sectional views that any lubricant used, is permitted to flow around the upper half of the shaft rings, and thus disperse itself to the lower half by frictional contact; as the thin brass prevents a free circulation.

The other example in this plate, No. 2, is of a smaller proportion than No. 1, but drawn at double the scale for the practical purpose of illustration clearly. In this case the brasses are fitted to the fore and aft faces of the rings, as well as the spaces between them; the base plate also does not extend much beyond the block; but excepting these two matters there is scarcely any difference in this arrangement and the one above it; there is one advantage, however, in both these examples over that by Messrs. Day that we may mention, and it is that there are adjusting keys inserted in the cap as well as the seating recess; by which addition fore and aft adjustments of the brasses are attainable, also that each portion of the brass fitted to the ring against the shaft is separate, and thus a saving of that material is effected.

THRUST-BLOCKS CONSTRUCTED BY MESSRS. PENN AND MESSRS. MAUDSLAY, PLATE 37.—As Messrs. Penn's example is at the head of this plate, our description refers to it first. The block is of a novel arrangement common only to the firm, and the peculiarity lies in the shape of the outline of the cap and seating being square in the end view as represented, while the brasses are circular, and in the base plate having ribs on it, fore and aft of the block, to resist the thrust of the propeller. Another feature is in the base plate having keys inserted at the sides of the seating for the purpose of lateral adjustment.

The cap is secured by bolts held with keys under lugs cast with the seating, and

double nuts at the top ends. The oil chamber and water channel are the usual kinds adopted by the firm, and are as efficient as any other.

The brasses are *enclosed* within the block entirely, and the aft ring on the shaft is much thicker than those beyond it. The adjustment of the brasses is attained by shifting the block by an adjusting key or keys at the aft end of the seating and base plate.

It will be noticed in the plan that the seating is enclosed or situated between the side ribs on the base plate, which is entirely different from the preceding examples we have noticed in this chapter, as in some cases the plate has been flat without the ribs above it that are used for additional strength. This block has been fitted to the screw-propeller shaft of her Majesty's ship *Warrior;* and is an illustration of Messrs. Penn's practice during the last fifteen years.

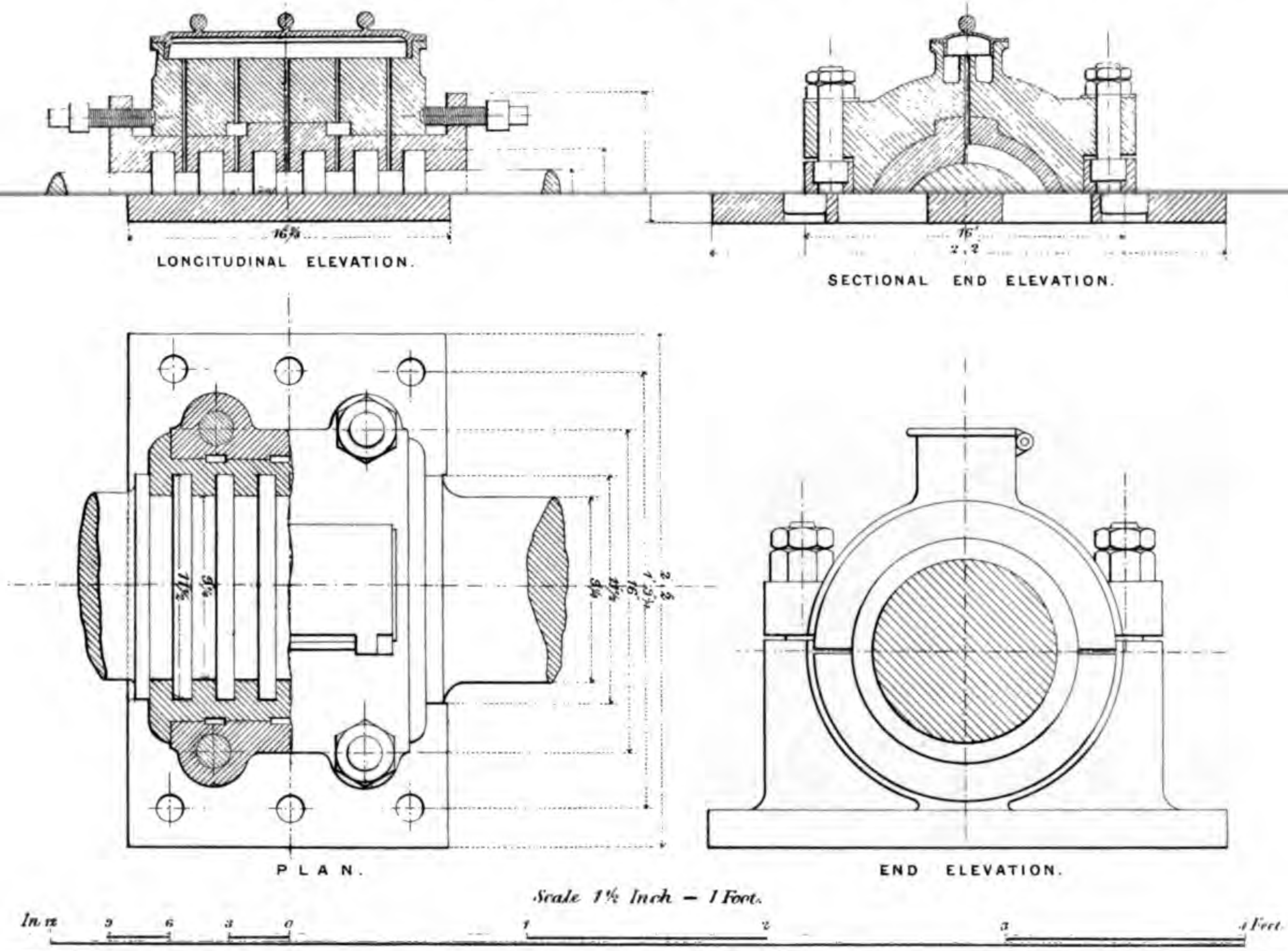
In the elevation a portion of the bearing for the base plate is shown, which consists of the wood between the plate and the support—also the angle iron and vertical stays, leading down to the girder plate forming the hull.

Referring next to the thrust-block by Messrs. Maudslay, a description of a similar example by that firm is given in page 189 of this work, and therefore does not require repetition here.

THRUST-BLOCKS CONSTRUCTED BY MESSRS. WATT AND MESSRS. DUDGEON, PLATE 38.—Messrs. Watt's arrangement consists of circular brasses bored out to fit the rings and spaces on the shaft; the length of the brasses exceeds that of the block, as will be seen in the sectional plan and elevation, and the purpose of this is, for adjustment by four set studs that are screwed through the flanges at each end, and bear against the cap and seating, as shown in all the views. The cap is secured by studs and nuts, and its position is ensured by "dowels" or projections cast with it, fitting into corresponding recesses formed in the seating. The base of the seating forms the plate also, and thus that detail as an addition is dispensed with; the size of the base exceeds that of the block sufficiently to form ample bearing surface and room for the nuts of the holding-down bolts. This thrust-block was fitted to the screw shaft of the engines of the twin-screw steam-ships *Medusa* and *Triton*, each engined 200 horse-power nominal collectively, constructed by Messrs. Watt in the year 1865.

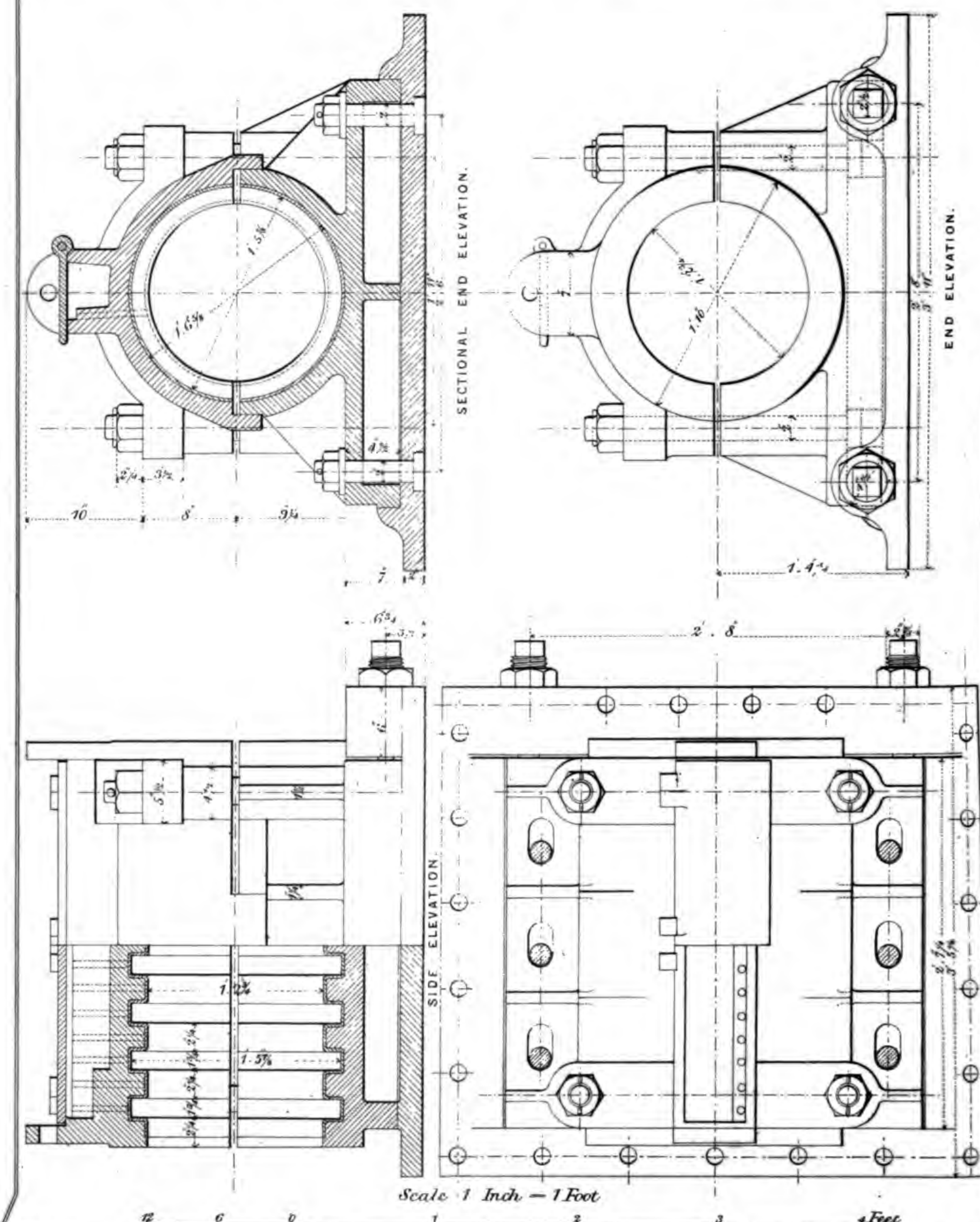
The thrust-block constructed by Messrs. Dudgeon, illustrated in this plate, must next be described; this is the ordinary type with the brasses *fixed* in the seating and cap without any means for adjusting them; the design of the seating and cap is an evidence of care as to the proper use of the metal, and the example as a whole may be selected as a good specimen of the class; it was fitted by the firm in the steamship *Ruahine*, a twin-screw steamer, engined 350 horse-power nominal, and her performance is described by them in Chapter VIII., commenced at page 85 of this work, in which also the advantages of twin-screw propulsion are practically discussed, combined with the relation of facts.

THRUST-BLOCK FITTED TO S.S. "MEDUSA" & "TRITON" BY MESSRS. J. WATT & Co.



EON.

THRUST—BLOCK CONSTRUCTED BY MESS^RS HUMPHRYS TENNANT & C^O



N.P. Burgh. Dres.

on the shaft. Messrs. Watt prefer set studs at each end of the brasses; but Messrs. Day and Humphrys adopt set studs at the forward end of the block only, and the former firm insert a key at the aft end for a centring adjustment. Messrs. Maudslay prefer *separate* adjustment for each ring face thrust surface, so that at any time independent relief or increase of resistance can be effected. Entirely reverse to this attainment Messrs. Penn and Dudgeon *fix* the brasses or face surfaces and the block; and Messrs. Laird and Ravenhill use keys in the flange connexion of the cap and seating for the adjustment fore and aft if required.

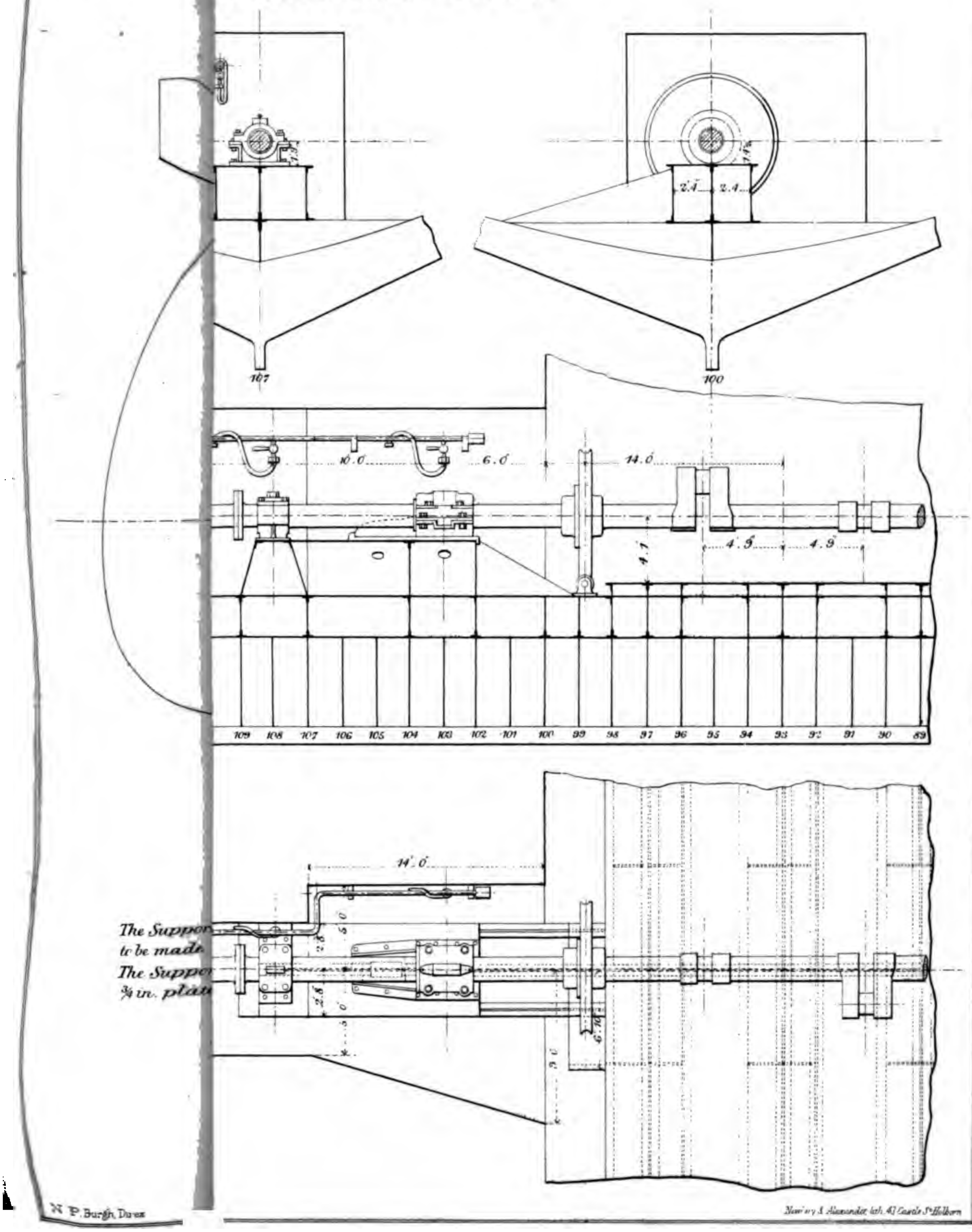
The supporting of the shaft is the least with Messrs. Maudslay's arrangement, as they use "horse-shoe" shaped thrust rings with a bearing block beyond them at each limit. Messrs. Ravenhill widen the spaces between the rings on the shaft, and use brasses between them only. All the other firms we have quoted prefer the shaft to bear fully on the brasses, or lining, so that the rings and spaces are in working contact with the supporting surfaces. The Table below will define the comparative proportions of those examples we have now been referring to.

TABLE OF THE PROPORTIONS OF THE THRUST-BLOCKS ILLUSTRATED IN THIS CHAPTER.

Maker's Name.	Diameter of the Shaft.	Diameter of the Rings.	No. of the Rings.	Total Area of Thrust Surface in sq. inches.	Diameter of Cap Bolts.	No. of Cap Bolts.	Diameter of Securing Bolts.	No. of Securing Bolts.
	Inches.	Inches.			Inches.		Inches.	
Messrs. Day and Co. . . .	14½	18	12	1072·071	1½	8	1½	14
Messrs. Laird	13¼	16½	8	607·507	2	4	2	13
Messrs. Ravenhill and Hodgson	12	15½	7	529·162	1¾	4	2	8
Do. Do.	4¼	6	7	84·529	1	4	1⅛	6
Messrs. J. Penn and Son .	17½	20½	9	805·820	2	6	1¾	8
Messrs. Maudslay, Sons, and Field	7¾	11¾	5	198·805	(Adjusting Bolts) 1⅝	5	1¼	10
Messrs. James Watt and Co.	7	9½	6	255·647	1	6	⅞	8
Messrs. J. and W. Dudgeon	9¼	11½	8	255·278	1¾	4	1¼	6
Messrs. Humphrys, Tennant, and Co.	14¾	17⅞	8	640·592	2	4	1¼	21

GENERAL ARRANGEMENT OF THE SCREW-PROPELLER, SHAFTING, STERN TUBING, THRUST AND SUPPORTING BLOCKS, SCREW ALLEY, FITTINGS, AND A PORTION OF THE HULL OF A MODERN ARMOUR-PLATED FRIGATE OF 4000 TONS, ENGINED 1000 HORSE-POWER NOMINAL, PLATE 40.—This plate is a faithful illustration of the *most modern* practice by the leading marine engineers in connexion with the details specified, and shows clearly the most efficient arrangement hitherto accomplished.

GE INC BLOCKS, SCREW ALLEY, FITTINGS AND A PORTION
O HORSE-POWER NOMINAL.



N. P. Burgh, Del.

Newman & Alexander, lith. 43 Castle St. Holborn

At the left hand extremity of the plate is the rudder, post, and end of the keel; leading on from this is the propeller, of the modern "Griffith's" type, 23 feet in diameter; the construction pitch is 23 feet, and the blades can be set from 20 to 26 feet pitches. Forward from the propeller is the stern post, tube, and the immediate portion of the hull in connexion. The stern post and tube are in section to illustrate the length of the bearing surfaces supporting the shaft and the diameter of the casing or tube on the same; also the length and diameter of the stuffing box and the gland's dimensions.

This is the commencement of the screw-alley or trunk in the hull for the shaft to pass through from the engine room. The shaft is supported next to the gland by a thrust-block which is arranged to resist the aft thrust of the propeller. Onward from this block is the first coupling, and next to it is the supporting block. The shafting is here divided into two lengths between the first coupling and that aft of the forward thrust-block; so that between the aft and forward thrust-blocks, there are three couplings and two supporting blocks, the latter being secured to frames formed on the foot plating above the keelson. Directly in front of the forward coupling is another block, and beyond it the main thrust-block; these are supported on plating and angle-iron framing which extends fore and aft for some distance beyond each block, and attached to the frame work of the hull below forming the foot plating.

The portions forward from this are the coupling and turning gear, also the engine cranked shaft, and the beams and plating for the engines and condensers to be secured to.

The plan of the longitudinal elevation just described is shown below it, and the transverse sections are situated over the elevation, and as each section is numbered to correspond with the number in the elevation, its particular reference can be easily recognised. In all these views the corresponding details are shown, also the water tubing and fittings required for lubrication.

The engines fitted in this hull are the return acting type with surface condensers; the cylinders of the engines are each 116 in. in diameter, and the stroke for the piston is 4 ft. The slide valves are the double-ported equilibrium type, and the link motion to move them is the usual slotted kind, raised and lowered by hand gear or by two small direct-acting engines. The condensers are the vertical tube arrangement; the condensed steam is drawn away by double-acting air pumps, and the circulating water—around the tubes and the steam inside them—is forced by two centrifugal pumps that are worked by separate quick speed engines.

The boilers are the ordinary tubular kind, their heating surface amounting to 19,000 sq. ft., and the total grate surface 700 sq. ft.

CHAPTER XIX.

A DESCRIPTION OF A NEW PRINCIPLE OF THE SCREW-PROPELLER.

By Arthur Rigg, Engineer, Chester.

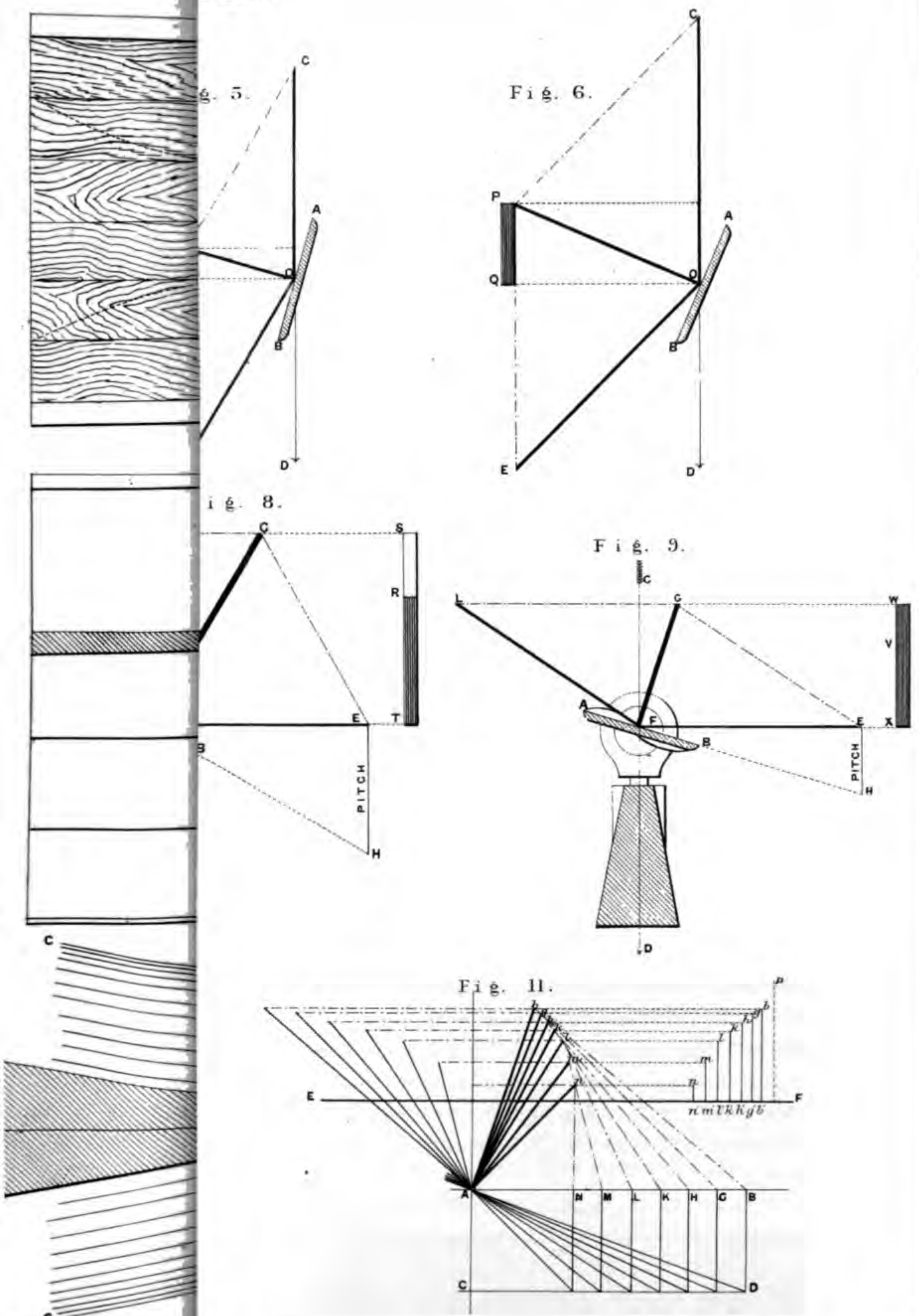
THE following remarks upon a new theory to explain the action of the screw-propeller have been written at the request of Mr. Burgh, and although some of the statements and experiments have already been published in isolated papers read before different societies, yet the author hopes that the following more complete reasoning may lead not only to a fuller understanding of a theory which has cost no small trouble to elaborate, but also may prove its truth so far as the present insufficient experimental data enable it to become known.

This theory differs from the ideal of a screw threading its path through the water as through a solid body, and it provides new explanations of the whole range of secondary causes whose influences bear most directly upon the best shape of this propeller.

The best, and indeed the only certain guides for research are the results of successful practice, supplemented by a series of experiments, arranged so as to furnish replies to any obscure questions. Even the curiously divergent statements which result from the empirical rules of practical men are not without great value in such investigations, while the multitude of forms of screw-propeller which have been patented or otherwise give a remarkable insight into the vague nature of ideas prevalent on this subject; some of these have shown good results; but such improvements have been caused more by accidental or involuntary amendments than by any intrinsic merit which the screws themselves possessed.

There are three main classes into which all screw-propellers may be separated, which are fully illustrated with other matters in the Plate K, namely:

ELLER.



F Burgh Direx

Newbery & Alexander lith 63 Castle St Holborn

Knowing the vertical position of the vane D, by marks made beforehand, the screw when set to work, drives a current of water obliquely, and the vane falls into line with it and indicates, by the pointer E, what is the angle of deflection; say X Y. When the pointer is now turned at right angles to the current, to X Z, the whole pressure will be exerted upon the 10 square inches of the vane D, and a corresponding amount upon the pin E. By placing a spring balance G, so as just to counterpoise this force, its indications will reveal the pressures of the currents. Both the direction and pressures ascertained by this experiment are given in the following Table:

EXPERIMENTS WITH THE SCREW STEAM TUG "DAGMAR" ON THE RIVER DEE, CHESTER, TO ASCERTAIN THE DEFLECTION OF THE REVERSE CURRENTS OF THE SCREW AND THEIR PRESSURES PER SQUARE INCH.

Radii.	Tug alone.				Towing Barge and Cargo.				Moored to a Post.			
Below the centre of the Screw.	Steam Pressure.	Speed of Screw.	Angle of Deflection.	Pressure per square inch.	Steam Pressure.	Speed of Screw.	Angle of Deflection.	Pressure per square inch.	Steam Pressure.	Speed of Screw.	Angle of Deflection.	Pressure per square inch.
Inches.	lb.	Revs.		lb.	lb.	Revs.		lb.	lb.	Revs.		lb.
17	60	144	35°	2·1	60	160	45°	1·0	46	136	72½°	·4
14	,,	,,	27½°	1·8	,,	,,	37½°	1·3	,,	,,	52½°	·8
11	,,	,,	25°	1·5	,,	,,	31°	1·3	,,	,,	50°	1·3
8	,,	,,	25°	1·2	,,	,,	31°	1·4	50	144	45°	1·1
6	,,	,,	27½°	1·2	,,	,,	31°	·9	,,	,,	42°	

This angle of deflection naturally exists at whatever quadrant of the circle the vane may be situated, whether above the centre, below, or else lying horizontally, and it indicates that the water is driven backwards as a twisted column (Fig. 3), which gradually increases in diameter by drawing into itself the adjacent particles of water until at last the rotation is destroyed, and it arrives at a state of rest. This diagram accurately represents the apparent reverse current in the case of the first experiment with the *Dagmar*, and makes it evident that the screw propels a volume of water obliquely backwards in addition to the vessel itself forwards.

An examination of this current shows that there is a loss of power due to this oblique action; and in order to determine the extent of this loss, another simple experiment was arranged in the manner shown by Fig. 4.

A B is the blade of the screw.

H K currents driven obliquely backwards.

C D a plate fixed in the current, so as to deflect the oblique flow of water, into one parallel with the screw shaft. Its inclination being so arranged that the angle

G F C = $\frac{1}{2}$ the angle G F K. When the currents H K or E F are impelled against this deflector, their course and direction are changed into F G, and a resultant pressure is given perpendicularly to the deflector plate C D. For the convenience of analysing this force, it is shown on an enlarged scale in Figs. 5 and 6, which represent oblique currents at 30° and 45° respectively. Similar letters correspond, therefore one description will suffice for both diagrams.

C D is the line of axis of the screw.

A B the deflector plates set at 15° and 20° (being $\frac{1}{2}$ the angle of the currents).

E O the direction and force of the current.

O C the direction into which it is deflected and passes backwards.

Now as this current is a compact mass of water and a continuous stream, it will behave much as would a succession of solid particles falling upon O, and being reflected the angles of incidence and reflection, E O A and B O C, will be equal, and the force E O = the force O C. These being equal and somewhat opposed forces, will give a resultant perpendicular to A B, whose magnitude is readily determined by drawing E P and C P parallel to O C and E O. The point of intersection, P, cuts the resultant and determines its magnitude, O P. This amount being the pressure upon the surface of the deflector blade, it only remains to take the component O P, which represents accurately the propelling power latent in the oblique current. As this power has been originally derived from the engine it is of course lost, and an arrangement, like that shown in Fig. 4, ought to recover the greater part of this force. Indeed, many experiments have shown the truth of this remark, and one of these has been already mentioned on page 22 of the present work. It was tried on a Tug belonging to the Grand Junction Canal Company, the screw had three blades and was 3 ft. diameter. It was arranged to pull against a powerful spring dynamometer, and tried first with the screw alone, then raised out of the water by a crane and the deflectors attached. The following results were obtained:

Screw alone—average pull	700 lb.
Screw and deflectors	880 lb.

being an increase of about 25 per cent.

Having now seen that a considerable current is driven backwards from the screw, and that much power is remaining latent, and ultimately lost through the current being oblique to the line of the ship's progress; there seems cause enough to doubt the correctness of the generally received opinion that this propeller screws itself through the water just like an ordinary solid body; for then it ought to have no reverse current and no "slip," there should be no power lost, and there could be no obliquity in the column driven backwards.

The screw does not in its progress through the water bear the most distant

resemblance to any action that might occur in a solid. Quite the contrary; for the particles of water can be driven in any direction, and their inertia forms the only obstacle to movement. This propeller is really an oblique paddle, and drives currents backwards nearly perpendicularly to the surface of the blade at whatever angle or pitch it may be fixed. Its action is exactly the same as that by which a fish swims, namely, by the flexure of its body; and the idea that water yields easily to the progress of a ship and becomes a solid resistance to the screw is so completely at variance with all reason, and so incapable of explaining observed phenomena, that it cannot be seriously maintained even when examined in the most cursory manner.

The artificial difficulties created by these incorrect theories have done much to produce the mystery and uncertainty which still surround the screw-propeller, and it is of the utmost importance to banish these notions altogether, and then to look upon it simply as an oblique paddle. Most of the difficulties then vanish, and a new and clearer light is thrown upon the whole question, while the investigation following will explain much that cannot now be unravelled, and point out the true principles upon which the best propellers are constructed.

Whatever may be the "pitch" of a screw, the amount of movement of any portion of its blades will really be measured by the circumference of that part: for instance, the extremity of the blade of a screw 15 ft. 6 in. diameter, will travel 48 ft. $8\frac{1}{4}$ in. in a direction at right angles to the progress of the ship. Now, so far as its propelling power is concerned, or in whatever way this movement can be viewed, it is really equivalent to moving a blade in a straight line across the ship's course; thus, if the ship be moving from south to north, the extremity of its screw-blade moves a distance of 48 ft. $8\frac{1}{4}$ in. from east to west in every revolution. It is true that this is a circular motion, but a rectilinear direction is exactly analogous to it in all its relations as a propeller.

Let Fig. 7 represent the section of a screw-blade whose inclination is 41°, and diameter 15 ft. 6 in.; F E will be the circumference = 48 ft. $8\frac{1}{4}$ in., and E H the pitch = 43 ft. $4\frac{1}{2}$ in. Now, whether the screw-blade A B moves from F to E, or the volume of water moves as a current from E to F, the result will be precisely alike; and this latter arrangement is the most convenient for examination.

It has been seen already by an examination of Figs. 5 and 6, that a current such as that from E to F striking against the blade A B, would become deflected to L, giving the angles E F H = L F A, and the resultant pressure G F obtained by drawing lines G L and G E parallel to E F and L F. In a similar manner the resultant G F is produced by the screw-blade moving from F to E, and is therefore the measure of the work done by one revolution of the screw at this particular portion of the blade. In consequence of the ship moving only along the line C D, that part of the work which results in its progress must be measured on C D. The water is free to travel in any direction, and will follow

Other circumferences are set off upon the line A B at G, H, K, L, M, and N, and all these give the resultants (which correspond to G F in Fig. 7), at the points *b*, *g*, *h*, *k*, *l*, *m*, and *n*. The perpendicular distance for any of these points to the line E F will be the reverse current at the corresponding diameter of the screw. All these results are given in the following Table:

TABLE OF REVERSE CURRENTS FROM DIAGRAM, Fig. 11.

Mean Diameter of Concentric Circle.		Position on the Figure.		Reverse Current Displacement.
Ft.	In.	Circumference Developed.	Reverse Current Line.	Feet.
9	6	A B	b b'	9·83
8	6	A G	g g'	9·08
7	6	A H	h h'	8·5
6	6	A K	k k'	7·33
5	6	A L	l l'	6·16
4	6	A M	m m'	4·33
3	6	A N	n n'	1·5

The last column in the above Table gives the reverse currents at the radii specified, and it will be noticed that they diminish very rapidly on reaching the central position, so that within about three feet diameter there is no reverse current at all. This space is generally occupied by a confused eddying mass of water full of vacancies, and known as "broken water." Unless this space is partially filled a loss of power takes place, for the currents set in motion by the blades are apt to run to this central semi-vacant place, instead of being driven backwards and propelling the ship. The methods generally adopted to counteract this tendency of the water to run inwardly are two in number. Either filling a great part of the space with a large globe, or else bending the screw blades forwards towards the stern, and so giving to the water a centrifugal motion just sufficient to neutralise its inward tendency.

The above data can now be conveniently employed to calculate the end thrust on the screw-propeller shaft, by dividing the whole area swept by the screw into concentric circles, and separately calculating the units of work due to every one of these. A few words of explanation will, however, first be necessary.

After the ship has once started, it travels 9·47 ft. for every revolution of the screw, and a column of water of this length is pushed backwards by every revolution. For example, the column whose area is 16·2 ft., and whose length is 9·47 ft. = a volume of 153·414 cubic feet, is displaced a length of 9·83 ft., as shown upon the diagram, Fig. 11, by the line $b\,b^1$. This is equivalent to a volume of 1508·06 cubic feet displaced 1 foot. Similarly, at the radius of 3 ft. 6 in., an area of 5·5 ft. multiplied by the same length of column, 9·47 ft., is reversed 1·5 ft., and is equivalent to 78·12 cubic feet moved 1 foot.

The sum of the units over the whole effective area of the screw gives the work done in one revolution, and as there are 1·616 revolutions per second, the work done can be ascertained.

The following tabular statement gives these particulars fully:

RESULTS DEDUCED FROM DYNAMOMETER EXPERIMENTS ON HER MAJESTY'S SCREW STEAMER "RATTLER."

Mean Diameter of Concentric Circle.		Area in Square Feet.	Length of Column.	Area × Length, being total Mass in Cubic Feet.	Displacement in one Revolution of the Screw.	Displacement × Mass, (being equivalent to Mass moved 1 foot).
Ft.	In.	Sq. ft.	Feet.	Cubic ft.	Feet.	Cubic ft.
9	6	16·2	9·47	153·414	9·83	1508·06
8	6	13·35	9·47	126·424	9·08	1147·93
7	6	11·98	9·47	112·450	8·5	955·82
6	6	10·21	9·47	96·688	7·33	708·71
5	6	8·64	9·47	81·820	6·16	504·01
4	6	7·07	9·47	66·952	4·33	289·90
3	6	5·5	9·47	52·085	1·5	78·12
						5192·55

This gives 5192·55 cubic ft., and as 35 cubic ft. of sea water = 1 ton, then 5192·55 cubic ft. = 148·35 tons, moved backwards one foot in each revolution of the screw; and as there are 1·616 revolutions per second, and the velocity of the current per second is 1·616 ft.

Now the work done may be defined as

$$\text{Pressure} \times \text{distance} = \frac{\text{Wt.} \times \text{vel.}^2}{2\,g}$$

$$\therefore \quad \text{Pressure} = \frac{\text{Wt.} \times \text{vel.}^2}{2\,g \times \text{distance}}$$

In this case

$$\text{Weight} = 148{\cdot}35 \text{ tons.}$$
$$\text{Distance} = 1{\cdot}616 \text{ feet.}$$
$$\text{Velocity} = 1{\cdot}616 \text{ feet.}$$

$$\therefore \quad \text{Pressure} = \frac{148{\cdot}35 \times (1{\cdot}616)^2}{2 \times 32\tfrac{1}{6} \times 1{\cdot}616}$$
$$= 3{\cdot}726 \text{ tons.}$$

= 3·726 tons pressure on the end of the screw shaft.

It is true that the ship travels 9·47 ft. per revolution, but this does not represent the "distance" in the foregoing equation; for it must be remembered that the water practically fills up the vacant space, and transmits the pressure from the screw to the mass of water 9·47 ft. long which is moved backwards. This ideal description best conveys the

action of the screw-propeller to the mind, but is not strictly accurate in fact, for the space is really never vacant.

Here, then, in this sum (3·726 tons) is represented the theoretical pressure upon the end of the screw shaft without making any deductions for losses due to friction and other causes; but it was found by the dynamometer that the real pressure was

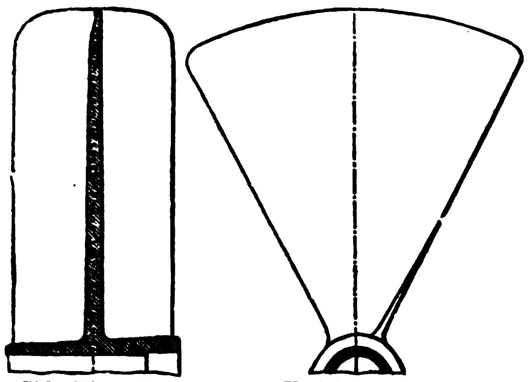
3·513 tons,

leaving a difference of ·213 of a ton or 4·26 cwts. to be accounted for by losses of various kinds, such as friction and the uneven flow of the currents. Such a calculation as this may be considered to give a result sufficiently close for practical purposes, and to be an important link in proving the accuracy of the new theory.

The preceding system of calculation is only available where the greater volume of the reverse current is within the length that the ship travels in one revolution. For instance, if in Fig. 11 the reverse current, $b\,b^1$, were extended up to $p\,b^1$ (say) 15 ft.; then it is evident that the column 2·47 ft. long will not supply enough water for the requirements of the reverse current, and a further supply will need to be drawn in from an area beyond that swept over by the screw blades. To what extent this question may affect the calculations of thrust, it is quite impossible to say; but no doubt it will modify them exceedingly.

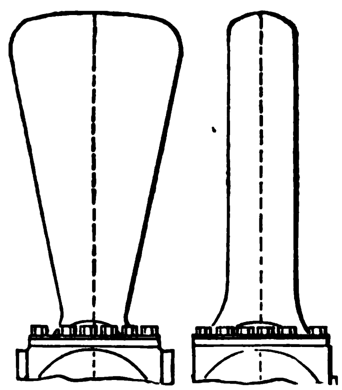
These investigations lead to the conclusion that the best screw-propeller should have a very rapidly increasing pitch, and that the true screw of uniform pitch is not desirable. It has been found that propellers made upon these principles drive ships faster with a saving of coal than those made on the common screw principle; and this in itself affords much warranty to the new ideas on this subject herein enunciated. Moreover, certain mysterious phenomena, such as the honeycombing of the back of leading corners of screw blades of short pitch, "negative slip," &c., may be readily explained by these investigations.

It may possibly be objected that the experiments adduced in confirmation of these views have been on too small a scale and of too circumscribed a character to warrant so wide a departure from ideas so generally acknowledged, and the author of the present chapter is fully alive to the exceeding desirability of further investigations; yet they do not alter the foregoing general principles, but may perchance modify to some extent the views herein propounded, or perhaps shed a new and clearer light upon the complex problem of screw propulsion.



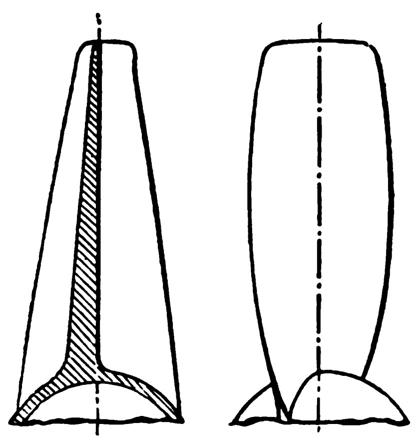
Elevations of the Blade of the Common Two-bladed Screw-propeller fitted to Her Majesty's Troop Ship *Simoom* by Messrs. James Watt and Co.

Fig. 68.



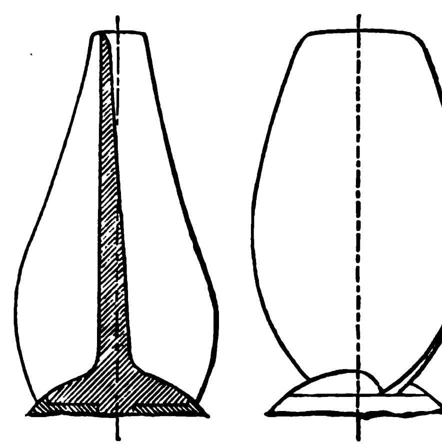
Elevations of the Blade of the Four-bladed Screw-propeller fitted to Her Majesty's Armour-plated Ship *Minotaur* by Messrs. J. Penn and Son.

Fig. 69.



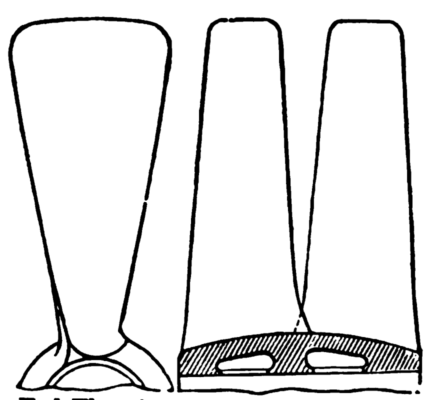
Elevations of the Blade of the Four-bladed Screw-propeller fitted to the Steam-ship *Allemannia* by Messrs. C. A. Day and Co.

Fig. 70.



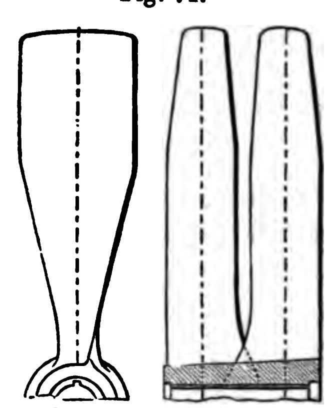
Elevations of the Blade of a Three-bladed Screw-propeller fitted to the Steam-ship *Surat* by Messrs. C. A. Day and Co.

Fig. 71.



Elevations of the Blades of a double-two-bladed Screw-propeller fitted to Her Majesty's Ship *Bullfinch* by Messrs. J. and G. Rennie.

Fig. 72.



Elévations of the Blades of the double-two-bladed Screw-propeller fitted to Her Majesty's Ship *Favourite* by Messrs. Humphrys, Tennant, and Co.

Fig. 73.

M. Mangin, from whom emanated the now well-known "Mangin" screw-propeller. The principle of this propeller is that the inventor has a propeller formed of double the length as ordinary; he then cuts it across in half, and puts one portion directly in front of the other, so that it becomes two propellers on one shaft. In the practice of construction each pair of blades are struck up as in the usual way, and shaped to suit the eye and mind of the designer, which Fig. 72 is an illustration of. In this case the sides are angular reversely in each view, the end elevation showing the blade widest at the top and narrowest in the side elevation. This propeller was constructed by Messrs. Rennie; its diameter is 7 ft. 3 in., pitch 11 ft. 4 in., and the maximum width 1 ft. 8 in., being fitted by them to Her Majesty's ship *Bullfinch*. The inventor, M. Mangin, not being content with double blades of a uniform pitch, advocates blades situated as before of unequal pitches, of which Fig. 73 is an illustration. Each blade is formed from two helices that are connected at one-fourth of the full width, starting at the leading edge; the forward pitch is 16 ft. 8 in., and the aft 20 ft.; the diameter of the screw is 16 ft., and the maximum width of each blade is 2 ft. 8 in. The outline is peculiar, as in each view the sides are angular and vertical reversely situated. Messrs. Humphrys, Tennant, and Co. constructed this propeller and fitted it to Her Majesty's ship *Favourite*. Of course it must be understood that these are two-bladed propellers with straight blades, as the others that have been referred to.

Another form of blade which, although having straight sides, is unlike any previously illustrated, is shown by Fig. 74. Here the blade leans back instead of being vertical from the boss, and the outline is a portion of a perfect screw having the leading side cut back. This blade is shown in two views as the other examples, and illustrates the fact that a number of narrow blades are equivalent in propulsive effect to two wide blades, and *vice versâ*. This propeller was constructed by Messrs. Rennie, and fitted by them to the steamship *Charkieh;* the diameter of the screw is 15 ft. 9 in., and the construction pitch is 19 ft. 6 in., the length of the tip of the blade being only 6 in., with a lean-back of 5½ in. from the centre of the root.

A similar example of cutting off the leading side of the blade is shown by Fig. 75. In this case more than one-half of the forward half of the perfect blade is taken away, as shown in the two views, so that a plan of the blade depicts that the forward part of the helix is stopped off at a certain distance from the centre of the boss for a little less than half of the width of the aft portion of the blade or helix. The vertical section of the blade is perpendicular, and the sides nearly straight; the propeller is 17 ft. in diameter, and the construction pitch 20 ft., the maximum width of the blade being 4 ft. It was constructed by Messrs. Maudslay, Sons, and Field, and fitted by them to Her Majesty's ship *Aurora*.

The ideas of Messrs. Dudgeon as to the best form of blade contrast extremely with those of Messrs. Maudslay, as shown by Fig. 76. The sides of the blade for half their vertical length are portions of a perfect helix, but above that the cutting and carving com-

mences, the tip is rounded aft and forward to a great extent—indeed, so much so that the natural outline of the top edge is entirely made away with: this will be seen from the two views. This propeller is 10 ft. 6 in. in diameter, 18 ft. pitch, and maximum width of the blade 4 ft. 3 in.

Now, this example is the modern form of blade for three aud four-bladed common screw-propellers, and, although of late construction, is of early adoption: this fact is proved by the Fig. 77, which is the side elevation of the original four-bladed screw-propeller, fitted by the late G. Rennie, Esq., to Her Majesty's ship *Dwarf* many years ago, or rather at the eve of screw propulsion. The blade is cut away so much that its natural outline is taken off entirely, which shows that the "cutting" and "carving" commenced with the use of the screw for propulsion.

Next is noticed Mr. Griffiths' blade. That gentleman has investigated this portion of the system thoroughly; in his article on it, he states, "I directed my attention to experiments with a view to ascertain what portion of the blade was the most effective. My first experiment with this object was to reverse the shape of the blades by putting the narrow parts to the outside, and the wide parts inside, or from and towards the centre of the disc—indeed, just the contrary to what was the usual practice, and I soon found I attained a better result with the blades formed in this manner than with any other." Mr. Griffiths treats on the vertical section of the blade also. He states, "I also find great advantage in constructing my screw-propeller blades to incline forward, the curve commencing from the centre of the length of the blade and extending to its point towards the ship, which result of advantage I account for in the following manner: when the ship is under 'way,' the screw is supplied with water from the after current, and this current has to be turned from its natural course, which is to fill up the space or channel that the ship has left, and also to supply the screw with propelling resistance, so that when the points of the blades bend towards the ship, they meet this current, and offer certain resistance to the power employed to work the screw, or what may be termed a greater bite to propel the ship."

It would appear from this statement that the straight blades must lose some power, or slip through the water instead of pressing full against it; yet in the face of this argument we find in practice that there is no disproportionate loss with either form of section of blade, *i.e.*, straight or curved.

The form of the Griffiths' blade will be understood from the illustration of it, Fig. 78. It will be noticed that the side elevation shows the vertical section is curved forward at the upper part, and the forward side is curved outwards over the boss, and above that it is curved inwards, while the aft side is a continuous curve in one direction from the root to the tip. The end elevation depicts that the leading side is cut away more than that opposite, and the cause for this is explained on the next page.

the speed of the hull. It may as well be observed, also, that the cutting away of the leading corner of the blade is not universal, for Messrs. Maudslay have generally constructed their common screw blades of the perfect shape; or as the helix and length on the line of the keel determine. The screw-propeller 24 ft. 6 in. in diameter, with four blades, fitted by them to Her Majesty's ship *Agincourt*, is the perfect-shaped blade; its width at the tip is 5 ft. 5 in., and at the root 3 ft., the sides being angular, but perfectly straight; the construction pitch of the screw is so fine that the length of the blade on the line of the keel is only 1 ft. 9 in. when it is set at 24 ft. pitch. For comparison another example of the same shape of blade can be taken, but the screw only 9 ft. in diameter, pitch 12 ft., width of blade at the tip 3 ft., at the root 1 ft. 3 in., and the length on the line of the keel 1 ft. $2\frac{1}{2}$ in. This propeller is one of two pairs of twin-screws, fitted by the same firm to Her Majesty's ships *Viper* and *Vixen*, hung in lifting frames, while the *Agincourt's* screw is fixed on the shaft, and overhangs the stern-post. With both these examples of screws there has been scarcely any vibration, and the cause for its obviation is that the pitch is rather fine in relation to the diameter, while the blades are made narrow, although of the natural form. Now if they had been wider, or the screws longer on the line of the keel, the effect would be that the leading corner would have broken up the current of water in front instead of cutting it, because the extra material put on would be too much in advance of the position of the duty of the blade, and thus be an obstruction to its forward motion or travel. Evidence of the truth of this has been given by Mr. Griffiths, who, in his article, states, on page 43:—"When I first commenced applying my screw-propellers, I put one on a vessel that was in dock, and I then dropped spots of candle-grease all over the blades of the propellers on both sides, and after some time, on the return of the ship to dock to alter the pitch of the screw, I found that the tallow had been worn off by the friction of the water on the propelling side of the front surface, just across the middle or widest part, and on the forward side of the leading edge of the back surface." That certainly was a sure as well as a simple means of knowing where the friction or resistance was the greatest, both on the fore and aft surfaces of the blade, and proved, too, that the leading corners in that instance had better have been cut away. So far is this certain, that when the blades are wide, as in Fig. 76, the leading and following corners are rounded excessively; indeed, so much so that the natural limit of the blade is entirely destroyed, and an artificial reduced shape takes the place of the complete outline. By doing this the vibration is reduced to the minimum, and thus the coarsely-pitched screw with the wide blade—due also to the length on the line of keel—can, by shaping it accordingly, be made to act as equally effective as the narrow blade, which remains untouched. In fact, it is but a matter of proportion *in toto* in relation to the speed of the hull.

General Arrangement of Modern Screw Propellers.—This section commences with

a description of the six-bladed screw-propeller, constructed by Messrs. Rennie, and illustrated by Fig. 80 on the preceding page. It will be noticed that the blades are inclined back in both views, and that they are almost perfect parallelograms in outline, so that the rounding off of the leading corners is not carried out at all in this case.

As a contrast, there is shown by dotted lines a two-bladed screw-propeller also, whose area of blade surface equals that of the original, by which it can be understood that a very little width and length comparatively only is required to make the surface of a two-bladed screw to equal that having six blades of a shorter length, but of the same pitch.

Next is illustrated by Fig. 81, a four-bladed screw, as used in the Royal Navy at present. The corners are but very slightly curved, so slightly that the natural outline is nearly preserved. As the shape of the boss appears square, a sectional plan of it is given which shows also how it is secured on the shaft, being by longitudinal keys and a nut on the end of the shaft.

The next example that is worthy of attention is illustrated by Fig. 82; in this case the blade is merely the Griffiths' shape, minus the lean-to or curve forward. The boss is spherical, as shown in the complete views and the sectional plan. This propeller has lately been constructed by Messrs. C. A. Day and Co., as also has the three-bladed example shown by Fig. 83. The blades in this case are adjustable, as in Figs. 80 and 81.

The next example is the latest three-bladed common screw-propeller, illustrated by Fig. 84, as Messrs. Dudgeon construct, as, indeed, do all the leading firms, not only for ships of heavy tonnage, but also for steam launches, yachts, &c.

Fig. 85 is the elevation of the modern two-bladed Griffiths' screw-propeller with adjustable blades, and the boss shaped as the frustrum of a sphere.

The arrangements of the modern screw-propellers have now been freely discussed: the conclusion refers to the original form of screw-propellers designed by the late Mr. G. Rennie, and fitted by him to Her Majesty's ship *Dwarf*, as far back as 1843, as illustrated by Fig. 86. It will be observed that the form of the blades are much as those of later design, and, excepting the spiral portion in front, it might be termed a modern two-bladed screw. Another form of two-bladed screw was designed and fitted to the *Dwarf* by Mr. Rennie, which is illustrated by Fig. 87, and contrasts materially with the present practice.

THE DETAILS OF MODERN SCREW-PROPELLERS.—This section contains a descriptiOD of the best practice by all the leading marine engineers for securing the boss of the propeller on the shaft, for securing the blade to the boss, and for preventing the blade-flange studs from unscrewing. These are three important matters, indeed, so much so, that the efficiency of the propeller properly depends on them.

SECURING THE BOSS ON THE SHAFT.—Messrs. Penn's practice is shown by Fig. 81 on page 221; they taper the shaft and the boss considerably. Thus, in the case of the

Another means to maintain the same effect is used by Messrs. Ravenhill and Hodgson, which is illustrated by Fig. 88 on the next page: in this case the shaft is secured by keys only, but these keys are situated laterally, in relation to the shaft and boss, on each side of the diameter of the taper, and fore and aft of its length. It will be understood that two segments are cut out of the circle of the shaft; into these spaces the keys fit, and thus the boss is fixed on the shaft laterally, and longitudinally. To prevent the keys withdrawing, they are fitted at the smaller ends with double nuts, which can be used to tighten them also if required; the under nut, it may be added, is seated on a raised washer as shown.

Messrs. Maudslay's practice is illustrated by Fig. 89, which is a transverse sectional view of the boss connexion with the shaft; they adopt two lateral keys also, but their method of securing them is entirely different from Messrs. Ravenhill's practice. In this case the keys are held by side pieces that are secured against the keys by studs; as shown in detail at an enlarged scale in this illustration also.

As these two latter examples belong to propellers of equal proportions, but constructed by two firms, it may be interesting to know how far the makers have considered alike in the main dimensions; and that the *Lord Clyde* and *Lord Warden* are the hulls to which the propellers are fitted. Both propellers are the double-bladed Griffiths' types, made according to all the modern improvements. Here are the main dimensions:

PROPORTIONS OF THE BOSS AND SHAFT CONNEXION OF THE PROPELLER FITTED BY MESSRS. RAVENHILL TO THE "LORD CLYDE."

	Ft.	In.
Length of taper in boss	4	$5\frac{1}{8}$
Diameter of shaft (forward end)	1	$9\frac{7}{8}$
" " (aft end)	1	$6\frac{1}{8}$
Width of key	0	10
Thickness of key	0	3
Longitudinal space between keys	0	4

PROPORTIONS OF THE BOSS AND SHAFT CONNEXION OF THE PROPELLER FITTED BY MESSRS. MAUDSLAY TO THE "LORD WARDEN."

	Ft.	In.
Length of taper in boss	4	0
Diameter of shaft (forward end)	1	9
" " (aft end)	1	5
Width of key	0	$8\frac{1}{2}$
Thickness of key	0	3
Longitudinal space between keys	0	$6\frac{1}{2}$

Besides the methods here explained, many makers key the propeller with one lateral key only, passing through the boss and shaft, and others with the key behind the boss, so that nearly all the mechanical modes have been adopted and tried.

But there is another practical question in this matter, and it is—How to get the boss

off from the shaft. It is all very well to be able to key it on tightly, but a time will come when it must be made loose again to take it off, and it is for that reason that the lateral keys at the sides of the shaft have been adopted, for they can be easily removed, and thus the boss driven off, or the shaft withdrawn; or, as Messrs. Penn prefer, the taper is greater, and thus, when the nut is withdrawn, the disconnexion is the simplest.

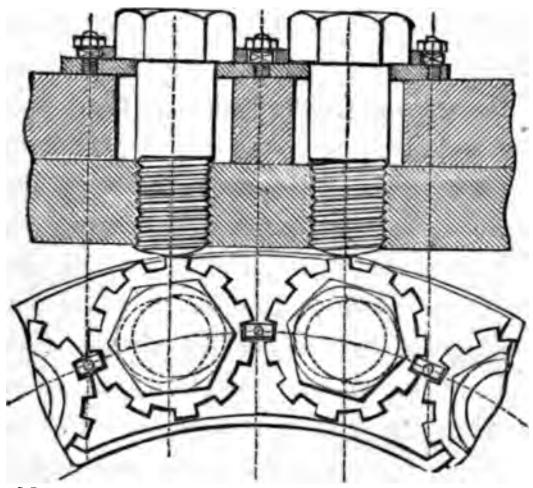
SECURING THE BLADES TO THE BOSS; COMBINED WITH THE MODERN PRACTICE OF PREVENTING THE FLANGE STUDS FROM UNSCREWING.—It is of course obvious that when the blades and the boss are in one casting, all the details now to be described are useless; but as we live in the days of gigantic means of warfare, so do we require gigantic propellers, and as those are costly as well as heavy, in the event of the fracture of any portion of them it is far better to replace the detail than the whole. But apart from that it has been deemed more advantageous to be able to adjust the angle of the blades to suit the velocity of the screw and speed of the hull, than to have a fixed angle, which if altered required a new propeller.

When Mr. Griffiths started his propeller he made the blades fixed on the boss, but he soon discarded that practice, for in his article he states, at page 41, "My attention was next directed to the construction of my screw-propeller in such a way as would combine the greatest possible stability with increased facilities for altering the pitch or replacing a broken blade in case of an accident;" and the illustration, Fig. 90, represents his mode of carrying out his requirements. This is the "key and wedges" arrangement, the "key" passing through the securing portion of the blade, and the metal in the boss surrounding it. The "wedges" are arranged in the key spaces in the boss, so as to alter the angle of the key and blade simultaneously. To prevent the keys and wedges from shifting when set, stop-plates and screw nuts are put on the extremities of the keys. This means has since been continually adopted with the addition of securing studs, as shown in the sectional elevation and plan.

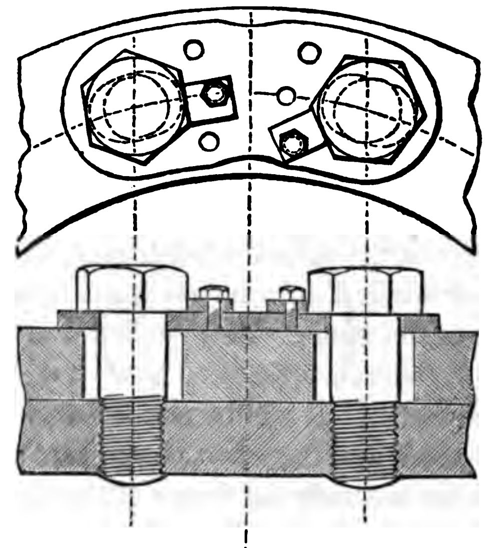
Now the adoption of the set or securing studs led to the non-adoption of the keys and wedges, *i.e.*, what was introduced as an assistant became the master entirely, and, therefore, the simple flange and stud connexion was introduced, which is now almost universal. Some firms, however, have lately used the original mode; for example, Messrs. Rennie, with their modern six-bladed propeller, prefer to adjust and secure the blades, as illustrated by Fig. 91, which is the key and wedge arrangement without the set studs and nuts.

It must not be forgotten, however, to mention that Messrs. Maudslay have always preferred to omit the keys and wedges, and use the studs and flange only, of which an example is illustrated by Fig. 92. This is a flat boss to which is secured the blades by studs screwed into flanges, and the complete outline forms a singular comparison with those in Figs. 88 and 90.

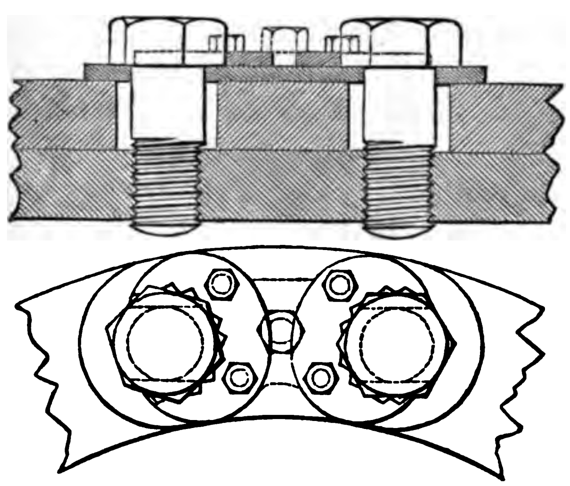
The general practice, when the propeller has three adjustable blades and the boss



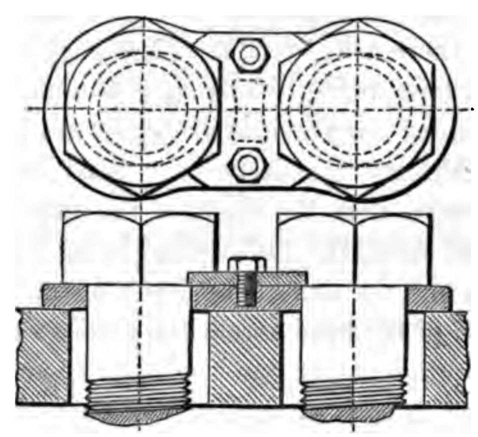
Messrs. Penn's method for securing the heads of Screw-propeller Flange-studs.
Fig. 94.



Messrs. Maudslay's method for securing the heads of Screw-propeller Flange-studs.
Fig. 95.



Messrs. Maudslay's method for securing the heads of Screw-propeller Flange-studs.
Fig. 96.



Messrs. Ravenhill's method for securing the heads of Screw-propeller Flange-studs.
Fig. 97.

globular, is shown by Fig. 93, which is an enlarged sectional plan of the boss of the propeller illustrated by Fig. 83, on page 221.

The reason why the studs and flange are sufficient to secure the blade is that the surface of the flange of the blade forms a perfect joint with the seat on the boss, and when thus connected the frictional contact is almost unlimited, so much so, indeed, that it is a rare occurrence for the largest and longest blades to shift around on their seats after being secured down by the flange studs.

The next proceeding is to describe the various methods for preventing the flange studs from unscrewing, commencing with Messrs. Penn's latest improvement, which is illustrated in two views by Fig. 94. The plan shows that the arrangement consists of the heads of each stud being surrounded by a ring of metal of suitable thickness, the centre periphery of which is indented or formed as a pinion with square teeth and spaces; between the rings on the pitch line of the flange studs are stop-studs, having square collars which fit into one of the spaces in each ring, and thereby lock them together; the rings are also further secured by nuts on the stop-studs, holding them down on the flange plate that receives the studs. This method has also the advantage of connecting the flange studs entirely, inasmuch that one head cannot turn without shifting the one next to it, and so on in succession. It will be noticed also that as each ring has eleven spaces on its outer edge, there are, therefore, eleven separate angles to which the main studs may be screwed up to for securing the flange of the blade to the boss.

Messrs. Maudslay's mechanical arrangement in this matter is illustrated by Fig. 95. The plan shows that each pair of studs are fitted with a flange plate, on which the head is fixed, and to secure the head from turning around a set-plate is used, the edge of which fits against either side of the head. This plate can be secured at three separate points by the same stud, and as the plate has four sides all unequidistant from the centre of the stud, there are of course twelve angles in this case, to which the main studs can be screwed up to for securing the flange of the blade. This method is the cheapest possible, and equally certain as the previous arrangement, but without the combined locking of the heads.

Messrs. Maudslay have used the arrangement shown by Fig. 96 also. The plan illustrates that the heads of the main-studs are held in position by separate plates of a curved form, the inside edge being indented angularly to fit the hexagonal edges of the stud, and the line of the depth of the indentations is a curve whose radius equals half the width of the head across the angles; each plate is secured by two studs, and as there are eleven indents, so can the heads be secured at eleven different angles; the firm sometimes prefer to connect each pair of main-stud heads by a single stop-plate secured by one stud, its extremities being as the single plate, the middle portion and the stud being shown by dotted lines in the plan and section of this illustration.

Messrs. Ravenhill's practice next must be noticed. That firm prefer the appliance shown by Fig. 97, which consists of a stop-plate situated between each pair of main-stud heads; in this illustration the plate fits the flats of the heads, but other forms of plates are used also, similar to the double plate by Messrs. Maudslay, just referred to. It will be noticed that with the four methods described, flange-plates are used for the main-stud heads to rest on, and also to receive the stop-studs of the set-plates, also that the holes for the main-studs in the blade-flanges are elongated sufficient to alter the angle of the blade to the minimum and maximum limits.

the joint, is considerable, and doubtless Messrs. Maudslay were prompted by that fact to design their very simple but efficacious mode for shifting and adjusting the blade, as shown by Fig. 99, which mode is but a stud—screwed through a projection formed in the flange of the blade—pressing against the flange stud, and thus the blade flange is started. Four of those studs are used with large blades, each situated in the corners of a square limit, and the method of adjustment is thus: if the forward edge of the blade nearest the sternpost were required to be turned towards it, the forward and aft adjusting studs on the left and right-hand sides would have to be turned to force against the two flange-securing studs opposite them, or to be screwed up, while those adjusting studs opposite must be turned to release their contact with the other two flange studs, or unscrewed; and *vice versâ* should the blade be required to be shifted in an opposite direction.

The same firm has arranged a mechanical means to resist the aft thrust of the propeller disturbing the position of the boss on the shaft, and thus relieve the boss cross-keys from the full shearing strain; this is illustrated by Fig. 100. It is that the end of the shaft has a groove formed in it, into which a ring in halves is secured by a metallic cord, and, as the boss presses against the ring it is prevented from shifting longitudinally. The end and ring are covered by a curved disc that is secured to the boss by studs, as shown in the sectional and complete views.

When the propeller is hung in a lifting frame many of the leading firms adopt wooden surfaces in a brass disc, as shown by Fig. 101, which receives the aft thrust of the extremity of the boss, and bears against the back of the frame support.

We have now ran through the leading particulars of the best practice by all the leading firms on screw-propellers, and conclude this chapter with a series of Tables containing the proportions of the modern screw-propellers illustrated in this work.

Headings of Table, No. 1.	Headings of Table, No. 2.	Headings of Table, No. 3.	Headings of Table, No. 4.	Headings of Table, No. 5.
Name of the Ship.	Adjustable pitches of the Blade.	Thickness of the Blade at the tip.	Mode of preventing the Studs from unscrewing.	Mode of Securing the boss on the Shaft.
Nominal horse-power of the Engines.	Mean pitch of the Blade.	Form of the lineal section of the Blade.	Diameter of the Boss of the Propeller.	Number of Keys.
Name of the Constructor.	Shape of the Blade.	Mechanical mode of securing the Blade to the boss.	Length of Boss.	Width of Key.
Type of the Screw-propeller.	Width of the Blade at tip.	Diameter of the Blade Flange.	Diameter of the flat end forward.	Thickness of Key.
Diameter of the Screw-propeller.	Width of the Blade at boss.	Number of the Securing Studs.	Diameter of the flat end aft.	Depth of Keyway in Shaft.
Construction pitch of the Blade.	Maximum width of the Blade beyond root.	Diameter of the Securing Studs.	Diameter of the Shaft in Boss forward end.	Mode of Securing Keys.
Pitch of the leading half of the Blade.	Number of the Blades.	Total area of the Securing Studs in square inches.	Diameter of the Shaft in boss aft-end.	Weights of overhung Propellers.
Pitch of the following half of the Blade.	Total area of the propelling surface of the Blades in square feet.		Length of the taper of the Shaft.	Weights of Lifting Propellers.
	Metal of the Blade.			Remarks.
	Thickness of the Blade at the root.			

No. 1.

TABULAR STATEMENT OF THE PROPORTIONS OF THE MODERN SCREW-PROPELLERS ILLUSTRATED IN THIS WORK.

Reference Numbers. Plate	Page	Name of the Ship.	Nominal horse-power of the Engines.	Name of the Constructor.	Type of the Screw-propeller.	Diameter of the Screw-propeller. Ft.	In.	Construction pitch of the Blade.	Pitch of the leading half of the Blade. Ft.	In.	Pitch of the following half of the Blade. Ft.	In.
18	124	H.M.A.P.S. "Minotaur."	1350	Messrs. Penn.	Four-bladed common screw.	24	0	Double pitch.	24	0	27	0
19	125	H.M.A.P.S. "Agincourt."	1350	Messrs. Maudslay.	Four-bladed common screw.	24	6	Double pitch.	24	10½	28	1½
20	127	H.M.A.P.S. "Lord Clyde."	1000	Messrs. Ravenhill.	Four-bladed common screw.	23	0	Double pitch.	23	5½	26	6
16	122	The P. and O.S.S. Surat.	500	Messrs. C. A. Day and Co.	Three-bladed common screw.	18	0	Uniform pitch.	24	10	24	10
B	17	Egyptian Gov. "Charkieh."	350	Messrs. Rennie.	Six-bladed common screw.	15	9	Uniform pitch.	18	0	18	0
A	15	H.M.S. "Lapwing."	80	Messrs. Rennie.	Three-bladed Griffiths.	8	6	Uniform pitch.	11	6	11	6
15	106	Greek Gunboat "King George."	150	Thames Iron Works Company.	Three-bladed common screw.	12	0	Uniform pitch.	15	0	15	0
15A	109	D.S.T.S.S.	100	N. P. Burgh.	Three-bladed common screw.	7	6	Uniform pitch.	10	0	10	0
12	81	H.M.A.P.S. "Lord Warden."	1000	Messrs. Maudslay.	Two-bladed Griffiths.	23	0	Uniform pitch.	23	6	23	6
11	79	H.M.A.P.S. "Lord Clyde."	1000	Messrs. Ravenhill.	Two-bladed Griffiths.	23	0	Uniform pitch.	23	6	23	6
21	129	H.M.A.P.S. "Warrior."	1250	Messrs. Penn.	Two-bladed Griffiths.	24	0	Uniform pitch.	30	0	30	0
10	77	H.M.S. "Arethusa."	500	Messrs. Penn.	Two-bladed Griffiths.	18	0	Uniform pitch.	23	0	23	0
25	138	H.M.T.S. "Orontes."	500	Messrs. Watt.	Two-bladed Griffiths.	18	0	Uniform pitch.	25	0	25	0
32	162	"H.M.S. "Aurora."	400	Messrs. Maudslay.	Two-bladed feathering.	17	0	Uniform pitch.	Flat.		Flat.	
34	164	A.S.S. "Victoria."	150	Messrs. Rennie.	Two-bladed feathering.	9	11	Uniform pitch.	Flat.		Flat.	
13	100	H.M.S's. "Viper" and "Vixen."	80	Messrs. Maudslay.	Two-bladed common screw.	9	0	Double pitch.	11	3	12	9
23	136	Gunboats.	50	Messrs. Watt.	Two-bladed common screw.	6	0	Uniform pitch.	7	6	7	6
9	75	H.M.S. "Favorite."	400	Messrs. Humphrys.	Four-bladed Mangin.	16	0	Double pitch.	16	8	20	0
C	17	H.M.S. "Bullfinch."	80	Messrs. Rennie.	Four-bladed Mangin.	7	3	Uniform pitch.	11	4	11	4
8	74	H.M.T.S. "Simoon."	350	Messrs. Watt.	Two-bladed common screw.	16	0	Uniform pitch.	20	0	20	0
17	123	H. and A.S.S. "Allemannia."	400	Messrs. Day.	Four-bladed common screw.	16	0	Uniform pitch.	25	0	25	0
14	102	Royal Mail S.S. "Ruahine."	175	Messrs. Dudgeon.	Three-bladed common screw.	10	6	Uniform pitch.	18	0	18	0
15B	111	Spanish Navy Steam Launch.	6	Thames Iron Works Company.	Three-bladed common screw.	2	6	Uniform pitch.	4	0	4	0
D	20	Steam Launch, R.N.	6	Messrs. Rennie.	Four-bladed common screw.	2	6	Uniform pitch.	3	6	3	6

No. 2.

Tabular Statement of the Proportions of the Modern Screw-propellers.

Reference Numbers. Plate	Reference Numbers. Page	Adjustable pitches of the Blade. Ft. In. to Ft. In.	Mean pitch of the Blade. Ft. In.	Shape of the Blade.	Width of the Blade at tip. Ft. In.	Width of the Blade at boss. Ft. In.	Maximum width of the Blade beyond root. Ft. In.	Number of the Blades.	Total area of the propelling surface of the Blades in square feet.	Metal of the Blade.	Thickness of the Blade at the root. In.
18	124	23 0 to 28 0	25 6	Angular straight sides.	5 3	3 0	Not required.	4	136	Gun-metal.	10
19	125	24 0 to 29 0	26 6	Angular straight sides.	5 5	3 0	Not required.	4	138	Gun-metal.	9
20	127	22 6 to 27 6	25 0	Angular straight sides.	5 3	2 7½	Not required.	4	136	Gun-metal.	9½
16	122	22 0 to 27 0	24 10	Pear-shaped curved sides.	2 4	2 10	5 4	3	90	Cast iron.	8
B	17	17 0 to 21 6	19 3	Nearly parallel straight sides.	1 6	1 6	Not required.	6	57	Wrought iron.	4½
A	15	9 6 to 13 6	11 6	Pear-shaped curved sides.	1 1	1 9	2 8	3	16	Gun-metal.	2¾
15	106	13 6 to 16 6	15 0	Forward side much curved back.	None.	2 1	4 5¼	3	47·4	Cast iron.	5
15A	109	8 0 to 12 0	10 0	Forward side much curved back.	None.	1 3¾	2 10½	3	20	Gun-metal.	3¼
12	81	21 0 to 26 0	23 6	Pear-shaped curved sides.	3 2⅜	3 4	7 4½	2	95·5	Gun-metal.	11
11	79	21 0 to 26 0	23 6	Pear-shaped curved sides.	3 3	4 5	7 0	2	99·16	Gun-metal.	10
21	129	27 0 to 33 0	30 0	Forward side much curved back.	3 4	5 8	8 3	2	120	Gun-metal.	9½
10	77	20 0 to 26 0	23 0	Forward side much curved back.	2 7	3 9	6 0	2	68	Gun-metal.	6
25	138	22 6 to 27 6	25 0	Pear-shaped curved sides.	2 6	3 9	6 0	2	69·2	Gun-metal.	6
32	162	17 6 to 22 0	20 0	Straight aft and curved forward sides.	Below tip. 3 10½	1 1¼	3 11	2	42	Gun-metal.	6
34	164	12 0 to 15 0	13 6	Straight vertical sides curved at boss.	2 8	0 11	2 8	2	18	Gun-metal.	3½
13	100	10 9 to 13 3	12 0	Angular straight sides.	3 0	1 4	Not required.	2	13	Gun-metal.	3¼
23	136	7 0 to 8 0	7 6	Angular straight sides.	2 3	1 1	Not required.	2	7·68	Gun-metal.	2
9	75	Cast with the boss.	18 4	Parallel straight and curved sides.	2 8	1 11	Not required.	4	17·7	Gun-metal.	6
C	17	Cast with the boss.	11 4	Angular slightly curved sides.	1 7½	1 3¾	1 3	4	18	Gun-metal.	3¼
8	74	Cast with the boss.	20 0	Angular straight sides.	8 0	3 3½	Not required.	2	40	Gun-metal.	4
17	123	Cast with the boss.	25 0	Parallel sides slightly curved.	2 4	3 3	3 4	4	75	Cast iron.	6
14	102	Cast with the boss.	18 0	Forward side much curved back.	None.	2 8	4 2½	3	30·4	Cast iron.	5⅛
15B	111	Cast with the boss.	4 0	Forward side much curved back.	0 9⅞	0 6¼	Not required.	3	2·3	Gun-metal.	1⅛
D	20	Cast with the boss.	3 6	Sides curved slightly opposite.	0 8	0 4	0 5	4	2	Gun-metal.	¾

No. 3.

Tabular Statement of the Proportions of the Modern Screw-propellers.

Reference Numbers. Plate	Reference Numbers. Page	Thickness of the Blade at the tip. In.	Form of the lineal section of the Blade.	Mechanical mode of securing the Blade to the Boss.	Diameter of the Blade Flange. Ft. In.	Number of the Securing Studs.	Diameter of the Securing Studs. In.	Total area of the Securing Studs in square inches.
18	124	2	Vertical.	Studs and flange.	3 10	15	$3\frac{1}{4}$	Gun-metal. 134·425
19	125	$1\frac{7}{8}$	Vertical.	Studs and flange.	4 $2\frac{1}{2}$	14	3	Gun-metal. 98·952
20	127	$1\frac{1}{4}$	Vertical.	Studs and flange.	3 9	14	3	Gun-metal. 98·952
16	122	$1\frac{1}{2}$	Vertical.	Bolts and flange.	2 10	6	$2\frac{1}{4}$	Wrought iron. 23·856
B	17	$\frac{3}{4}$	Lean back $5\frac{1}{2}$ in.	Neck with key and wedges.	1 $1\frac{1}{2}$	Diameter of neck 7 in.	Length of neck 9 in.	Area of neck 38·484
A	15	$\frac{1}{2}$	Curved forward $3\frac{1}{4}$ in.	Bolts and flange.	1 2	6	$1\frac{1}{4}$	Gun-metal. 7·362
15	106	$\frac{7}{8}$	Vertical.	Bolts and flange.	1 11	8	2	Wrought iron. 25·128
15A	109	$\frac{3}{4}$	Vertical.	Bolts and flange.	1 5	7	$1\frac{1}{2}$	Wrought iron. 12·369
12	81	$1\frac{1}{4}$	Curved forward $11\frac{1}{4}$ in.	Studs and flange.	4 5	16	$3\frac{1}{2}$	Gun-metal. 153·936
11	79	$\frac{11}{16}$	Curved forward $11\frac{1}{2}$ in.	Studs and flange.	3 $11\frac{1}{2}$	10	$4\frac{1}{2}$	Gun-metal. 159·040
21	129	$1\frac{1}{4}$	Curved forward $15\frac{1}{2}$ in.	Neck with key and wedges.	Neck 1 6 Flange 3 $2\frac{3}{4}$	Width of key 9 in.	Thickness of key $2\frac{3}{4}$ in.	Area of neck 254·469
10	77	1	Curved forward $7\frac{3}{8}$ in.	Flange with bolts and nuts, and neck with key and wedges.	Neck 1 3 Flange 2 6	Width of key $7\frac{1}{2}$ in., and 6 studs.	Thickness of key $2\frac{1}{2}$, studs' diar. $1\frac{1}{2}$ in.	Gun-metal. 10·602
25	138	1	Curved forward $10\frac{3}{4}$ in.	Neck with key and wedges.	Neck 1 2 Flange 2 $2\frac{1}{2}$	Width of key 7 in.	Thickness of key $2\frac{1}{2}$. in.	Area of neck 153·938
32	162	1	Vertical.	Neck and lever.	Neck 1 $1\frac{1}{4}$	None.	None.	Area of neck 137·886
34	164	$\frac{3}{4}$	Vertical.	Neck and lever.	Neck 0 $7\frac{1}{2}$	None.	None.	Area of neck 44·178
13	100	$\frac{3}{4}$	Vertical.	Studs and flange.	1 11	12	$1\frac{1}{4}$	Gun-metal. 14·724
23	136	$\frac{5}{8}$	Vertical.	Studs and flange.	1 1	4	$1\frac{1}{2}$	Gun-metal. 7·068
9	75	$1\frac{1}{2}$	Vertical.	None.	None.	None.	None.	None.
C	17	$\frac{3}{4}$	Vertical.	None.	None.	None.	None.	None.
8	74	$1\frac{3}{4}$	Vertical.	None.	None.	None.	None.	None.
17	123	$1\frac{1}{2}$	Vertical.	None.	None.	None.	None.	None.
14	102	$\frac{7}{8}$	Vertical.	None.	None.	None.	None.	None.
15B	111	$\frac{1}{4}$	Vertical.	None.	None.	None.	None.	None.
D	20	$\frac{1}{4}$	Vertical.	None.	None.	None.	None.	None.

No. 4.

Tabular Statement of the Proportions of the Modern Screw-propellers.

Reference Numbers. Plate	Page	Mode of preventing the Studs and Keys from unscrewing.	Diameter of the Boss of the Propeller. Ft. In.	Length of Boss. Ft. In.	Diameter of the flat end forward. Ft. In. Ft. In.	Diameter of the flat end aft. Ft. In.	Diameter of the Shaft in Boss forward-end. Ft. In.	Diameter of the Shaft in Boss aft-end. Ft. In.	Length of the taper of the Shaft. Ft. In.
18	124	Combined indented rings and stop-studs.	4 0 square.	4 0	3 10	3 10	1 11	1 2	3 9
19	125	Separate set plates and studs.	4 7 square.	4 7	4 2½	4 2½	1 11	1 5	4 7
20	127	Double set plates and studs.	4 0 square.	4 0	Octagonal. 3 8	3 8	1 9	1 5	4 0
16	122	Grooves in the nut and stop-pin.	4 6	4 1½	1 9	1 10	1 4½	1 2½	3 11
B	17	Double nuts and pin on the ends of the key.	3 2	3 8½	1 6	1 6	1 2¼	0 11¾	3 8¼
A	15	Grooves in the nut and stop-pin.	2 3	1 8	1 6	1 6	0 7⅝	0 6½	1 6½
15	106	Bolts, nuts, and stop-pin.	2 7	2 3½	1 3¼	1 3	0 9	0 8	2 3
15A	109	Double nuts and pin.	1 10	1 8¼	0 9	0 8⅛	0 8½	0 5¾	1 8
12	81	Separate set plate and stud.	5 6	4 5	3 3	3 3	1 9	1 5	3 11
11	79	Double set plates and studs.	6 6	4 6	4 0	5 0	1 9⅞	1 6½	4 5½
21	129	Stops in the flange and packing pieces fitted between the key and boss.	6 7	4 8	4 8½	4 8½	Forward bearing 1 11½	Aft bearing 1 3½	None.
10	77	Double nuts and pin.	5 0	4 0	3 0	3 0	Forward bearing 1 8	Aft bearing 1 3	None.
25	138	Double nuts and pin in the ends of the key.	4 6	3 9	2 5	2 6	Forward bearing 1 3	Aft bearing 1 0	None.
32	162	None.	3 3	1 10½	2 6 × 2 0	Lever and coupling.	Forward bearing 1 7½	Aft bearing 1 1	None.
34	164	None.	2 0	1 3	1 0 × 1 2	Lever and coupling.	Forward bearing 0 11½	Aft bearing 0 5	None.
13	100	Separate set plate and stud.	2 0½	1 11	Neck of bearing 0 10	None.	Forward bearing 0 9¾	Aft bearing 0 8	None.
23	136	Double nuts and pin.	1 8	1 6	Neck of bearing 0 7	0 8	0 7	0 5	None.
9	75	None.	Central 2 0	3 3	2 2½	1 8½	1 2¼	1 0	2 9¼
C	17	None.	Central 1 6	2 4	1 1	1 0	0 7½	0 6	2 1
8	74	None.	Central 1 8	3 6	1 11	1 4½	1 1¾	0 11½	2 9
17	123	None.	4 0	3 8	Neck of bearing 0 15	1 10	1 2	1 0	3 5½
14	102	None.	Central 2 1½	2 7	1 3	1 1	0 9½	0 8	2 7
15B	111	None.	0 4⅛	0 6½	0 3⅝	0 2⅝	0 2⅛	0 1⅝	0 5⅞
D	20	None.	0 5	0 3¾	0 3½	0 3½	0 1¾	0 1¾	0 3¼

No. 5.

Tabular Statement of the Proportions of the Modern Screw-Propellers.

Reference Numbers.		Mode of securing the Boss on the shaft.	No. of Keys.	Width of Key.	Thickness of Key.	Depth of Keyway in Shaft.	Mode of securing Keys.	Weights of the Propellers keyed on the Shaft.				Name of Ship.	Weights of the Lifting Propellers.		
Plate	Page			Inches.	Inches.			Ts.	cwt.	qr.	lb.		Ts.	cwt.	qr.
8	124	Longitudinal keys and nut on shaft.	2	3	2	1 in.	Flange and nut on shaft.					H.M.T.S. "Orontes."	10	4	1
9	125	Side keys and stop-ring on shaft.	2	9	$3\frac{1}{2}$	8 in. space between.	Side plates and studs.	22	17	0	0	H.M.S. "Aurora."	6	11	0
0	127	Side keys and flat plate.	2	10	3	4 in. space between.	Double nuts.	22	0	0	0	A.S.S. "Victoria."	1	18	0
6	122	Longitudinal keys and nut on shaft.	(4) 2 at each end of the boss.	$2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$ in.	Nut on shaft.	9	15	0	0	H.M.S.s. "Viper" and "Vixen."	1	0	3
B	17	Longitudinal key.	1	$4\frac{1}{2}$	$1\frac{3}{4}$	1 in.	Riveted.	5	1	0	0				
	15	Longitudinal key.	1	2	$1\frac{1}{8}$	$\frac{3}{4}$ in.	Riveted.	1	5	0	0				
5	106	Longitudinal keys and nut on shaft.	2	$1\frac{3}{4}$	$1\frac{1}{8}$	$\frac{3}{4}$ in.	Nut on shaft.	2	11	1	13				
5A	109	Cross-key and nut on shaft.	1	$3\frac{1}{2}$	$1\frac{1}{8}$	Through boss, nearly central.	Flange of blade.	1	1	2	0				
2	81	Side keys and stop-ring on shaft.	2	$8\frac{1}{2}$	$3\frac{3}{8}$	$6\frac{1}{2}$ in. space between.	Side plates and studs.	17	9	0	0				
1	79	Side keys and flat plate.	2	10	3	4 in. space between.	Double nuts.	18	0	0	0				
	75	Longitudinal keys and nut on shaft.	2	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$ in.	Collar and nut on shaft.	4	19	0	0				
	17	Longitudinal keys and nut on shaft.	2	2	$1\frac{1}{4}$	$\frac{7}{16}$ in.	Nut on shaft.	1	0	0	0				
	74	Cross-key and bearings fore and aft.	1	6	$1\frac{3}{4}$	Through boss, central.	Split end.	3	15	0	0				
	123	Longitudinal keys and nut on shaft.	(4) 2 at each end of the boss.	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$ in.	Nut on shaft.	7	4	1	0				
	102	Cross-key and longitudinal key.	1 cross. 1 long.	Cross 5 Long. 2	Cross $1\frac{3}{8}$ Long. $1\frac{1}{2}$	$\frac{3}{4}$ in.	Split. Closed.	2	13	2	0				
B	111	Longitudinal key and nut on shaft.	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{16}$ in.	Nut on shaft.	0	1	0	$13\frac{1}{4}$				
	20	Longitudinal key and nut on shaft.	1	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{16}$ in.	Nut on shaft.	0	0	2	0				

Remarks.

All the propellers particularised in these five Tables are examples of the latest and best practice by the leading firms, and the completeness of them is only equalled by their truth, as every dimension and other particulars are given by the makers. The utility of the Tables is apparent also from their completeness and arrangement; as care has been taken to classify all the particulars in a consecutive manner, or similarly as their relation is one to the other in actual practice. For example, having settled the diameter and pitch of the propeller, the next step is to determine the area of the blade, which is subsequent to the

e, and the widths to both of those limits. Next is known the metal forming the blade, by which the thicknesses are settled, and the lineal section. After this comes the matter whether the blade shall be adjustable or fixed on the boss, and if the former, the anical mode of securing the blade to the boss is considered; and suppose it is by a flange and studs, the diameter of the flange is rmined from the angle of the blade at the root, and the number of the studs that can be screwed into the seat on the boss with a certain eter of stud; the area of which multiplied by the number used, settles the stud-area for securing the blade according to the material . So much for the blade and its connexion; next is determined the best means for preventing the studs from unscrewing, and that being factorily arranged, the diameter and length of the boss can be settled now, if not before, also the diameter of the shaft and the mode ecuring the boss on it; and, finally, the weight of the whole propeller.

CHAPTER XXI.

A COMPARATIVE REVIEW OF THE PRINCIPLES OF SCREW PROPULSION, DESCRIBED IN THIS WORK BY THE MOST EMINENT MARINE ENGINEERS, WITH THE OPINIONS OF OTHER AUTHORITIES.

By N. P. Burgh.

INTRODUCTION.—It is an axiom of importance that when an authority of note on any scientific subject writes his opinions under his name for public use, he is far more deliberate than one of lesser position and information; indeed the difference of care widens in proportion to the difference in knowledge possessed by the two writers. The reason for this is that the professor who knows his subject thoroughly knows too the danger that results from a *supposititious* conclusion, and that, as his opinion is of importance and belief, an imaginary or even a loose way of expression may lead to a mistaken construction. Another feature in this case is that the more the authority knows, the more concise is his explanation, and therefore it is the more ready to be understood and applied. Now, the force of these remarks applies to the eminent marine engineers who have written the concise and practical articles on screw-propulsion under their names in this work, in the following order:

An Introduction, by G. B. Rennie, Esq.

The History of the Griffiths' Screw-propeller, by the inventor, Robert Griffiths, Esq.

The Geometry of the Paddle Wheel, by C. Barclay, Esq., of the firm of James Watt and Co.

On Twin-screw Propulsion, by Messrs. J. and W. Dudgeon.

General Remarks on the Twin-screw System, by Captain T. E. Symonds, R.N.

The Practical Results of Lignum Vitæ Bearings for Screw-propellers and Screw-shafting, by J. Penn, Esq., M.I.C.E., &c.

A Description of the Feathering Screw-propeller as fitted to certain Ships by Messrs Maudslay, Sons, and Field.

The Principles and Practice of the use of Thrust Blocks for Resisting the Thrust of

"*The friction* will depend on the smoothness and equality of the surface of the blades, and their velocity through the water.

"*The vibration* will be influenced by the form of the blades, and the uniformity of their resistance throughout their surface."

Of course a great deal depends on the form of the blade as to the action of the propeller; the shape most universal in the Royal Navy at present is the "Griffiths'" which has been compared with others in the preceding chapter; the inventor's opinions are that: "Nature has given to *swift* birds and fishes tapered and pointed wings and fins, but to the *slow* birds and fishes, broad wings and fins. In proportion to the speed with which bodies move through fluid, will be the amount of the particles of that fluid put in motion, and as the *points* or outer edges of the propeller blades move through the water at double the speed of the *inner* part or at half of the diameter of the screw, also being nearer the boss, the blades consequently require to be only one quarter as wide at the points as at the widest part near the boss, to put a column of water in motion equal to the screw's diameter; for example, with a two-bladed screw of 17 or 18 ft. in diameter, revolving at 60 revolutions per minute, the points of each blade will follow each other every half second, and as each blade strikes the water and puts it in motion it will sustain it in that state or very nearly so until the next blade strikes it, hence the slight difference, in retarding the speed of the engines, between a 2, 3, or 4-bladed screw. For when the screw is at work each blade strikes and drives the water back through its disc between the blades at a speed due to the angle or pitch of the screw, and the after-current follows it, which the next blade strikes, and as the screw is moving forward with the ship, the current that has been made to move backwards by the preceding blade strikes the leading edge of the blade on the forward side, which causes great wear on that part; and it is my opinion that if the resistance which is thus made to the blades were *lost power*, it would have been fatal to the screw as a propeller; but the power thus exerted from the water on the forward sides of the blades is given back by acting on the inclined surface, and thus forces itself around the screw, so that the only loss incurred is the friction due to the contact.

"In designing screw-ships the most important feature for ensuring the required speed is by having the after part, or run, made so as to allow time for the flow of water to fill up the space the ship has left, as well as to supply the screw with water; for, obviously, unless the screw can meet with a sufficient supply of water freely, a good result can never be obtained. It is of little consequence, however, what is behind the screw, or rather what becomes of that water after it has gone beyond the screw, as the screw has advanced from it, but undoubtedly any obstruction to the water getting freely to the forward side of the screw will cause a serious loss in the speed of the vessel."

give what may be called its *real slip;* and that real slip is the true value of the velocity impressed on the water by the propeller. This requires special attention in the case of screws, which almost always work in water that is following the vessel.

"Another circumstance also requires attention, when the propeller lays hold of water that is already in motion through the action of the vessel, viz., that the change of pressure produced in the water by the action of the propeller on it is transmitted to some part of the ship's bottom, and thus *the resistance of the ship is altered.* The alteration of resistance so produced constitutes a difference between the *total thrust* and the *effective thrust* of the propeller."

Our opinion of the "action of the screw-propeller" is that *the action is constantly changing* in proportion to the speed of the hull and velocity of the screw's revolution. For instance, when the screw is churning the water at any part of the length of the blade, that disturbance must affect the volume above and below it; and when the velocity is increased or decreased, the position of the churning is raised and lowered accordingly. It will be understood from this conclusion that the churning of the water by the screw is constant either of more or less disadvantage to the working of the engines and speed of the hull accordingly as the churn-position is changed. The next point, therefore, to be settled is where is the *worst* position for the churning to occur, for the best position will be against the propulsion; and in knowing the worst we shall more readily arrive at the means of eluding it altogether, which, of course, is the aim of all those interested in the screw-propulsion of steam ships.

The propelling surfaces of the blade of any screw-propeller are at two parts of the blade, fore and aft, and the duties of these parts are entirely in opposite directions.

The forward part is the leading corner of the blade; as that is the advancing surface and is the first portion that separates the water as it advances through the volume. Now the duty of this part of the blade is to glide around the water that surrounds the metal forming the boss—we use the term "glide around" as it best expresses what the duty should be—and not disturb it or the surrounding water outside the outer extremity of the blade; but if the form of the leading corner is not in accordance with the velocity and advance speed then the water will be "*churned*" *forward.* The forward churning, it must be noticed, is a resistance also; and if the blades meet with a resistance as they advance, until that is overcome the speed is nil; this incurs also what is termed propulsive friction, which is apart from "hull" or "skin" friction. The propulsive friction is then the result of permitting the leading corner of the blade to beat about, and bruise the water it should *not* disturb; and the permitting emanates from an inferior knowledge of the principles by the designer of the blade.

We stated previously that the position of the churning is changeable, but the fact was constant. Now as the "worst part" of the blade for churning is the leading corner,

pulsive effect of the screw can only be termed a portion of the power required to move it at the velocity attained.

The lifting of the water is the greater evil of the two, and to arrive at an estimate of the amount of power it absorbs is to consider the cause for the lifting first, and then the result of its occurrence.

The cause for the water being lifted by the blades of the screw-propeller during its revolution is, that the angle of the blade is too acute in proportion to the velocity and advance speed of the hull, and thus the edges of the blade carry up, if not around, a certain quantity of the water that is within the "race" of the propeller.

The area of the race is equal to that of the diameter of the screw, but the race is better expressed as the area of the direct action of the propeller than by any other literal method of description.

The loss of power that results from the lifting of the water may be taken at about 10 to 20 per cent., the former being, of course, a rare attainment, while the latter is too general by far.

The cause for the water being thrown back, or impelled behind, is that the water in front of the blade is greatly disturbed by it, and as that water is the resisting quantity against which the *next* blade acts; it does not constitute solid water, but rather a series of eddies or broken currents finding their way to the aft side of the blade, and that surface *drives* them into their normal condition. Another cause is that the angle and shape of the blade not only disturbs the forward water, but carries on that operation behind too, when the forward becomes the aft water; for it must be remembered that the aft resistant was the forward at one time, and thus how the action of the forward edge of the blade greatly improves or deteriorates the effect of the aft surface.

The portion of the aft surface of the blade that propels the ship is the portion that presses mostly against the water; with blades that are widest at the tip, as Fig. 68, in page 214, *one-third* of the length from the tip is the main propelling surface; but with blades shaped as Fig. 71, in the same page, and Fig. 79, in page 217, it is at the *centre* of the blade for about one-third of its length; these proportions are evidences from actual practice and are there non-contradictory.

According to Mr. Rigg, " The screw does not in its progress through the water bear the most distant resemblance to any action that might occur in a solid. Quite the contrary; for the particles of water can be driven in any direction, and their inertia forms the only obstacle to movement. The propeller is really an oblique paddle, and drives currents backwards nearly perpendicularly to the surface of the blade at whatever angle or pitch it may be fixed. Its action is exactly the same as that by which a fish swims, namely, by the flexure of its body; and the idea that water yields easily to the progress of a ship and becomes a solid resistance to the screw is so completely at variance with all reason, and

fan, which drives through its disc a column of water equal to its diameter, and at a speed due to the pitch or angle of the blades with the screw-shaft; and, whether the ship is at her moorings or under way, the thrust on the screw-shaft equals the resistance of the column of water that is driven through the screw, as it were, and counterbalances the power exerted by the engines—minus friction—so that the resistance thus obtained by forcing the water backwards is also equal to the force or thrust that is transmitted to the screw-shaft for propelling the ship. The water in which the screw works is an eddy that follows the ship at the same speed, or nearly so, varied by the proportion existing between the form and length of the run and the speed at which the ship is driven through the water; and therefore if a patent log were placed in the screw opening, when the ship is propelled by canvas only, it would not even approximately indicate the speed of the ship."

Professor Rankine states, in his work, where treating on the "slip":

"It appears that the effect is *always to produce a waste of power*, when the propeller works in water that has been previously set in motion by the vessel; in other words, when there is a difference between real and apparent slip.

"With regard to the *efficiency* of propellers, or the ratio borne by the useful work done in driving the vessel, to the whole work done in moving the propeller, the following results (when friction is left out of account) are applicable to all kinds of propelling instruments:

"When the propeller works in previously still water, there is a loss of work simply proportional to the slip of the propeller; so that the efficiency is represented by—

$$-\frac{\text{Slip of propeller}}{\text{Speed of propeller}}.$$

In the case of screws or other obliquely acting surfaces, the loss stated above comprehends the effects of rotatory or transverse, as well as of backward slip of the water.

"When the propeller works in water previously set in motion by the ship, there is, in the first place, a loss of work proportional to the *real slip* of the propeller relatively to that moving water, and then a further loss of work proportional to the *square of the previous velocity of the water*."

Our explanation of "slip" is expressed in page 241 of this work.

We must notice next another class of "slip," termed "negative" slip of the screw and positive slip of the ship, which is really that the ship moves *faster* than the propeller *can* push her forward.

As we have illustrated three examples of four-bladed propellers that have indicated apparent negative slip in their working in this book, we have introduced a portion of a paper by E. J. Reed, Esq., C.B., "On some recent Cases of Negative Slip in Screw-propellers," which that gentleman read at the Institution of Naval Architects, in March, 1866:

"During the last year or two a novel form of screw, having four blades, each formed with two distinct pitches, has been introduced, having previously been used with satisfaction, I believe, in the French Navy. On the 28th of April, 1864, a screw of this description, 24 ft. 6 in. in diameter was tried in the *Achilles*, set at a mean pitch of 29 ft. 7 in., the forward half of the blade having a pitch of 27 ft. 11 in., and the following half a pitch of 31 ft. 3 in. The revolutions at full power were 46·667, and at half power 37·5, giving a mean speed of screw of 13·624 knots in the former case, and of 10·947 knots in the latter, the corresponding speeds of the ship being 14·358 knots and 11·879 knots. In other words, at full power, the ship's speed exceeded that of the screw by about ¾ths of a knot, and at half power by nearly a knot. In December of the same year, and again in March of the following year, further trials of the same screw set at different pitches were made and gave similar results. The following is a summary of them:

ACHILLES.

No. of Trial.	Date of Trial.	Pitches of Screw.		Number of Revolutions of Screw per minute.	Rate of Screw.			Speed of Ship in Knots per hour.
		Forward Half.	Following Half.		Forward Half.	Following Half.	Mean Rate.	
		Ft. In.	Ft. In.					
1	28 April, 1864.	27 11	31 3	46·667	12·857	14·391	13·624	14·358
2	" "	"	"	37·5	10·331	11·564	10·947	11·879
3	14 Decr., "	24 3	27 5	49·562	11·861	13·410	12·635	13·349
4	15 " "	"	"	40·25	9·632	10·890	10·261	11·132
5	28 " "	"	"	52·833	12·643	14·294	13·468	14·291
6	15 March, 1865.	24 3⅛	26 4⅛	54·583	13·085	14·207	13·646	14·322
7	" "	"	"	45·25	10·847	11·778	11·312	12·049

"Now, it may occur to some gentlemen to say that they are not surprised to find that the speed of the ship exceeds the rate of advance of the leading half of the screw, or even of the mean rate of advance of the two halves taken together, as it may well be that the following half of the blade, which is the portion that determines the velocity with which the water is actually driven off from the screw, is that which really should be considered as determining the rate of the screw's advance. But it is to be observed that the admission of this assumption does not remove any difficulty that may exist in accounting for the excess of the ship's speed above the rate of the screw's advance; because, if you will kindly examine the figures, you will observe that in the fifth trial the speed of the ship and of the following half of the screw are precisely alike (to the second place of decimals), while in the second, fourth, sixth, and seventh trials, the speed of the ship actually exceeds that of the following half of the blade. Neither half of the screw comes up to the ship in speed.

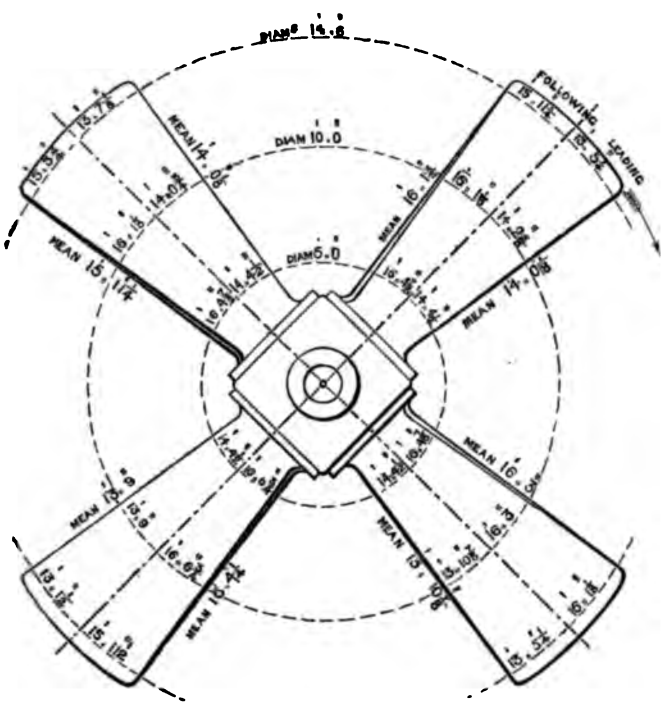
"A similar screw was fitted to the *Minotaur*, and on trying her, in September of last

year, we found that, with a rate of screw of 14¼ knots, we had a speed of ship of 14¾ knots, the diameter of the screw being 24 ft., the mean pitch 25 ft. 2 in., and the revolutions 57½. A few days later, in the same month, the *Bellerophon* was taken to the Nore for a preliminary trial of her engines, and gave, with a similar screw, 23 ft. 6 in. in diameter, a still more extraordinary result; for, with 57·83 revolutions, and a mean pitch of 21 ft. 8¼ in., giving a speed of screw of 12·387 knots only, the ship advanced at the speed of 13·645 knots, thus over-running the screw, so to speak, to the extent of 1¼ knots per hour. In the following month, the *Agincourt* was tried with a double-pitched four-bladed screw, of 24 ft. 6 in. in diameter, set to a pitch of 24 ft. This screw was driven at the rate of 55½ revolutions per minute, giving a rate of advance of 13·161 knots per hour, the ship's speed being 13·879 knots, or nearly ¾ths of a knot in excess. The same ship was tried again in December, with the same screw set to a slightly reduced pitch, viz., 23 ft. 4 in., which, with 61½ revolutions, gave a rate of advance of 14·161 knots, the ship's speed being 15·433 knots, thus exceeding the speed of the screw to the same extent as the *Bellerophon*, viz., 1¼ knots. In November, 1855, the *Lord Clyde* was tried, with a like form of screw, 23 ft. in diameter, set to a pitch of 22 ft. 6 in. She made 56½ revolutions, giving an advance of screw of 12·513 knots, and a speed of ship of 13·534 knots—a difference of a little more than a knot. The same ship was tried again last month, with the pitch reduced to 21 ft., the engines making 58 revolutions, giving a speed of screw of 12·020 knots, and a speed of ship of 13·312 knots, the difference being in this case more than 1¼ knots.

"I now come to the case of the *Amazon*, a wooden sloop of about 1000 tons, which was also fitted with a similar screw in the first instance, and with which some curious and interesting results were obtained. Her four-bladed screw was of 15 ft. diameter, and set, in the first instance, to a mean pitch of 15 ft. $\frac{9}{16}$ in.; and, in order that you may fully comprehend the manner in which the measurements were taken, I have prepared a diagram (Fig. 102) upon which they are fully set forth. They are taken, you will observe, at three points on each half blade, the mean of the three measurements being the first mean. A mean of these means is then taken for the two halves of each separate blade, and thus a mean pitch for each blade is obtained. The mean of all these pitches for the four blades is lastly taken, and this is what is meant by the mean pitch of the entire screw.

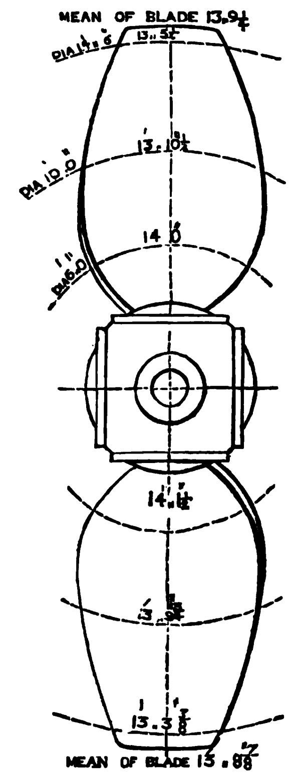
"On the first trial, the *Amazon's* engines made 75 revolutions per minute, giving a speed of screw of 11·133 knots, and a speed of ship of 11·494 knots. The pitch of the screw was then reduced to 12 ft. 6 in., and the vessel again tried, the revolutions rising to 86⅓, giving a speed of screw of 10·65 knots, and a speed of ship of 12·079 knots, or a negative slip, so called, of very nearly a knot and a half. If you compare this with the former trial, you will find this very remarkable result, viz., that although the speed of the

screw decreased nearly half a knot, that of the ship increased by fully that amount! As the speed of both screw and ship were still unsatisfactory, a two-bladed Griffiths's screw was fitted, and set to a pitch of 15 ft., being also of that diameter. With this screw the revolutions rose to $88\frac{2}{3}$, and the speed of the ship to 12·171, that of the screw being 13·125, thus giving nearly a knot of positive slip. As the engines were, however, still below their designed number of revolutions, the pitch of the new screw was reduced to 13·9$\frac{1}{16}$ (the pitch measurements being shown on the second diagram, Fig. 103), at which



End Elevation of the Screw-propeller fitted to Her Majesty's Screw-ship *Amazon*, causing Negative Slip.

Fig. 102.



The Boss of the Four-bladed Screw-propeller, fitted with two "Griffiths'" Blades and two Blank-flanges, fitted to Her Majesty's Screw-ship *Amazon*, causing Positive Slip.

Fig. 103.

pitch the revolutions were $94\frac{1}{3}$, the speed of the screw 12·804, and that of the ship 12·396, the slip still remaining positive, but not amounting to half a knot.

"The question now arises—In what manner are we to account for the many examples of apparent negative slip with screw steamers, that I have detailed to you? and I am afraid I shall not succeed in furnishing you with any very satisfactory answer. Let us first see what is meant by slip. Let us suppose that a screw-ship is dragged through the water by some wholly external force; it is obvious that if the screw is held at rest

relatively to the ship, or, in other words, is not allowed to turn round, the water will press upon the fore side of the screw-blades as the ship advances with a pressure due to her speed If, while the ship continues to move, the screw is now turned slowly ahead, the pressure on its fore side will be diminished proportionately: and, according to the popular view, we may say, that by increasing the revolutions of the screw, you may go on diminishing the pressure until it is got rid of altogether, and that this will be the case when the speed of the screw in advance is equal to the speed of the ship. There will then be no pressure whatever on either side of the screw, supposing the water to remain at rest. If we now desire to abandon the external force, and propel the ship at a uniform speed by means of the screw, the screw must obviously be driven faster, and thus press upon the water behind it, until the momentum which it impresses upon the water which it drives astern is equal to the whole momentum which the ship impresses upon the water in the forward direction. It was this extra speed of the screw in the backward direction that is known as *slip*, or, in other words, the difference between the ship's speed forward and the screw's speed backward.

"We may divide the momentum impressed by the moving vessel upon the water round her into two parts: first, the momentum generated in the water which she drives before her; and, second, the momentum generated in the water which follows her. The whole resistance of the ship's motion is the sum of these two. Now, if we suppose the screw to work in the following stream, it can only act on part of that stream, and can only destroy part of its velocity. The momentum communicated to the water which follows the ship must, therefore, be less than the forward momentum which the water would have constantly communicated to it if the ship were propelled by sails. But the resistance of the ship is measured by the whole momentum which is being continually supplied to the following stream, added to the momentum generated at the bows; the reaction on the screw, therefore, when the slip is negative, supposing it to act in partly stopping the water which is following the ship, must, of necessity, be less than the resistance opposed to the vessel's motion.

"Or, view the question dynamically. Suppose the ship goes V knots, and is of such a form that, if she were propelled by sails at that rate, a stream of water would follow in her wake with a resultant forward velocity of v knots. Imagine a screw to work in this stream, going at the rate of u knots with regard to the ship; what would be the dynamical result? This: that all the water affected by the motion of the ship would have a forward momentum even after the action of the screw had taken place. The unbalanced resistance acting to retard the motion of the ship would consist of—

1. The momentum impressed upon the water at the bows;
2. The momentum of the stern stream at v knots;
3. The momentum of the remainder of stern stream at $(V—u)$ knots.

And we have really nothing whatever to put upon the opposite side of the account, as the cause or equivalent of these!

"My impression is, after giving much consideration to the subject, that the cause of negative slip must be further sought in quite another direction, and that it is really to be found in the elasticity of the fluid. All former disquisitions upon this subject have proceeded upon the assumption that the water is practically inelastic, and that the motion imparted to the water against which the screw-propeller strikes is equal, and only equal, in velocity to the velocity of the screw; whereas a little reflection will suffice to show that this can scarcely be the case, and that, on the contrary, it is most probable that the water struck by a high-speed screw is driven off at a much greater velocity than that of the screw, and that the momentum imparted to it is proportionate to this velocity."

Our opinions as to the cause for negative slip of the screw-propeller are based on the fact that if the ship moves faster than the propeller advances, as per pitch × revolutions, there is an *exchange* of power, or that the ship *drags* the propeller that should push her along. Now the main feature here, then, is, what causes the hull to drag the screw, when that instrument is doing all possible to push the hull at the same time? The best answer that we can give is that it is the blades that drive the water forward against the aft quarters of the hull, and therefore a forward current is caused that follows the hull, and that when the aft surfaces of the blades meet this current, a greater resistance occurs than when the screw works in "solid" or still water. This is more certain than otherwise from the fact that screw-propellers of a *certain* form and proportion *always* produce negative slip; for were not that the case the phenomenon would be varied in its existence, whereas now it is constant to one given cause. There is no great mystery, either, in the cause, when it is considered that the forward motion of the current must be a far better resistant than solid or still water, because *momentum* is in action, and therefore the aft surface of the blade is acting against a volume that is moving forward instead of a solid or even a receding resistant. Another fact is that as the water in front of the screw is impelled so as to strike the hull, a certain power in the screw is taken up by that operation, and thus its speed is proportionately reduced by the friction incurred, but happily the power thus expended is not entirely wasted, as it is when the impelling of the water occurs behind the blade; for it must be borne in mind that any movement of the water caused by the screw is power expended, and if that water does not strike the hull, the power is entirely lost in the surrounding current.

The cause for negative slip, therefore, can be summed up in a few words in this way: the power expended to cause the water to impinge on the aft quarters of the hull is not lost, and the force of the momentum of that water can be *added* to the forcing properties of the screw, and the quantity added will be the sum of the difference between the resistant effect behind, and the impinging effect on the hull forward of the blade.

We have next to explain how to determine this quantity; this can only be done after its occurrence in this manner: Suppose a ship moved 15 knots per hour, but the screw only worked up to 14·75 knots in calculation, there would be a *loss of* ·25 *of a knot in theory* which practice contradicted; and as practice in this case is only power expended, we have no hesitation in stating that the screw gave out the same power as the hull performed, in the way of expending the power fore and aft of the blades. Now, if the screw does not lose any power—friction excepted—by causing negative slip, it may be questioned why the operation is not always admitted; the answer is that the "friction" is the barrier to its universal adoption—a matter that we shall now explain.

Frictional Resistance.—This is a subject which refers to the amount of power that is absorbed by the water in contact with the propeller and the hull, when both are in motion at a certain speed.

Taking into consideration the propeller first, we must explain how the friction is incurred by its action. The incurrence is produced by the propeller acting against the water, and by the water acting against it. Now, this of course is of a twofold character, and may be said to be the maximum limit of the incurrence of friction, while the minimum is when the propeller is the sole agent.

The greatest amount of friction is produced when the propeller is causing "negative slip," and the result of this emanates from the propeller impelling the water forward—which is propeller friction only—and then impelling the *same* volume backwards, which is a *combination* of water and propeller friction together. It is, indeed, but a matter of how much power is expended in throwing the volume of water forward, to begin with, and then how much of that power is *carried away* by the ship, as the remainder is the amount left in the water, which becomes the resistant plus the gravity, and therefore an excess of friction is produced over that with the ordinary circumstance of propulsion. Now, the circumstance referred to is when the propeller causes "positive slip," as then the propeller pushes and beats about the water, which, when thus served, does not react against the blade, because the propeller blades have time to advance from that volume, and thus act in a *new* current. It is, then, evident from these conclusions that with high speed and high proportion of positive slip the friction involved is the least, but with slow speed and negative slip the friction is the greatest. That is to say, that, with the same engines and pressure of steam, any difference of the velocity of the propeller must be due to the friction incurred by it—that due to the engines being excepted—and that the quicker the propeller revolves the less the friction will be proportionately. It is therefore better to drive a screw at a high velocity with a little positive slip than otherwise, because momentum is lending its power to that of the steam; whereas when the propeller is working heavily or "grinding" the water, as it may be termed, the centrifugal action is nil; and thus what might be used an an assistant, is converted into a "drag" on the motive power.

The power absorbed by the water surrounding the screw will depend also greatly on the depth of the immersion of the screw, or its position in relation to the aft quarters of the hull, as in the case of twin-screws; or when the propeller overhangs the rudder; so that in some cases when the screw is low in the water and moves slowly, or is free from the hull currents, the ship is being propelled faster than when the screw is higher, while the indicated power is reduced, because the speed of the engines is slackened by the screw working harder in the water, but yet doing more duty than before.

Having in the preceding remarks fully investigated the friction of the screw-propeller and the principles on which it is based, we consider next the friction of ships, as the propeller has everything to do with that function. We have, in treating this subject, held the same views as generally acknowledged in the profession by the authorities, among whom may be mentioned Professor Rankine, but where we have differed the cause has been explained.

The skin friction or resistance the hull meets with is a resistant that is formed of three bodies of water, all of which are in operation at the same time; the first is forward water, extending from the bow to the widest part of the hull, and is a direct resistant or *impinging;* the second is the *sliding* water which is on each of the parallel sides of the hull; and the third is the water that is the compound of the two former, termed the aft water, in which the propeller works.

According to the general practice in the present day, it is considered that the resistance of the water against the ship can be computed thus when the surface is clean:

Smooth wood,	friction	in water	= 1 lb.	per	square	foot.
Iron painted	,,	,,	= 1·4 lb.	,,	,,	
Clean copper	,,	,,	= ·7 lb.	,,	,,	

when the ship is moving at the rate of 10 knots per hour. The skin friction increases when the surface is foul from 1·5 to 2 of that when it is clean.

The resistance is increased also as the square of the increase of the speed; for example, suppose the resistance to be 2·1 lb. per square foot at a speed of 10 knots per hour, it will be increased to 4·2 lb. per foot with a speed of 14 knots per hour.

The Resistance the Hull meets with due to the Action of Waves.—The motion of the ship as she advances *produces* waves. At the surface of the water the pressure then may be said to be constant, but below this the increase or decrease is according to the height and depth of the wave. Then as to the effect by speed: when the velocity of the water past the vessel is *minimum* a *wave crest* is caused, but when it is *maximum* a *wave trough* is produced.

Every ship, according to her form, impresses some motion in the direction of her advance on the particles of water at and near her bow; while the particles amidships move to a greater or less degree backwards; so that if we consider the ship as fixed the flow

of the water is retarded at the bow and stern and accelerated amidships. The retardation at the stern is somewhat greater than at the bow, because the particles of the water at the stern undergo the action of adhesion; it is evident, therefore, that every ship is *necessarily* accompanied by two *wave crests* and an intervening *trough*, more often known as a *leading* wave, and a following *wave*, the latter being termed the "wake."

THE RESISTANCE THE SHIP MEETS WITH, DUE TO DISTURBED WATER SURROUNDING HER IN THE FORM OF EDDIES.—This is a compound of minute currents and whirlpools, said to be between the ship and the currents outside. The velocity of the formation of these eddies against any portion of the hull is proportionate to the speed of the ship and her form; the height of the eddies at the sides of the hull are also due to the same causes. The resistance to the motion of the ship due to the production of these frictional eddies by a certain portion of the hull is known as follows: The area of the surface immersed must first be known; and next the coefficient of resistance, which multiplied together = the *augmented surface*, or the resistance of the hull, including her weight and dimensions.

At 10 knots per hour for the speed of the ship the eddy resistance is one pound avoirdupois per square foot of augmented surface, and varies for other speeds as the square of the speed.

Another Rule for the probable resistance of ships is to *multiply the augmented surface by the square of the speed in knots, and divide by* 100 *for clean vessels.*

The *coefficients* of augmentation vary in proportion to the shape and frictional condition of the immersed portion of the hull; but, taken broadly, they range from 1·100 to 1·356, the least being for clean copper and fine lines, and the greatest for bluff hulls and foul surfaces.

THE ENGINE POWER REQUIRED FOR A GIVEN SPEED OF THE HULL.—In computing the probable engine power required at a given speed for the hull, allowance must be made for the power wasted through slip, through wasteful resistance of the propeller, and through friction of the engine. The proportion, borne by that wasted power to the effective or *net* power employed in driving the vessel, of course varies considerably in different ships, propellers, and engines; but in several good examples it has been found to vary little from 0·63; so that as a probable value of the indicated power required in a well-designed vessel we may take—net power × 1·63.

Now, an indicated horse-power is 550 foot-pounds per second, and a knot is 1·688 ft. per second; therefore an indicated horse power is $\frac{550}{1\cdot688} = 326$ *knot-pounds*, nearly, or 326 lb. of gross resistance overcome through one nautical mile or knot in an hour. If we estimate, then, the net or useful work done in propelling the vessel as equal to the total work of the steam divided by 1·63, we shall have $\frac{326}{1\cdot63} = 200$ knot-pounds of net work done in propulsion for each indicated horse power. Hence the following—

RULE.—*Multiply the augmented surface of the hull in square feet by the cube of the speed in knots, and divide by* 20,000, *the quotient will be the probable indicated horse power.*

The divisor in this rule, 20,000, expresses the number of square feet of augmented surface which can be driven at one knot by one indicated horse power; it may be called the *coefficient of propulsion.* With a short after-body for the hull, the coefficient of the friction may be about 16,000, but when the after-body is the proper length, but fore-body too short, it is about 19,000.

Rule for the probable speed of the hull of a known ship.—*Multiply the indicated horse power by the coefficient of propulsion—say for clean ship* 20,000—*divide by the augmented surface, and extract the cube root of the quotient,* which is the probable speed required.

A CALCULATION OF THE PROBABLE SPEED OF HER MAJESTY'S SHIP "WARRIOR."

Displacement on Trial . . . . 8997 tons.

Draught of Water . . . {Forward 25·83 feet. / Aft. . . 26·75 „

Water-lines.	Sine of Obliquity.	Square of Sine.	4th power of Sine.
L.W.L	·370	·1369	·01874
2W.L	·315	·0992	·00984
3W.L	·290	·0841	·00707
4W.L	·265	·0702	·00492
5W.L	·235	·0552	·00304
6W.L	·165	·0272	·00074
Keel	·000	·0000	·00000
Means		·0674	·00583

$1+(4\times\cdot0674)+\cdot00583=1\cdot275$, Coefficient of Augmentation.

Half-girths from Body-plan Feet.	Simpson's Multipliers.	Products.
21·0	1	21·0
27·2	4	108·8
30·8	2	61·6
34·6	4	138·4
38·8	2	77·6
41·5	4	166·0
42·6	2	85·2
44·0	4	176·0
44·0	2	88·0
44·0	4	176·0
43·3	2	86·6
42·1	4	168·4
Carried Forward		1353·6

Half-girths from Body-plan. Feet	Simpson's Multipliers.	Products.
		1353·6
40·3	2	80·6
38·1	4	152·4
36·0	2	72·0
35·0	4	140·0
32·0	1	32·0

Divide by	3)1830·6	Sum.
Divide by ½ number of Intervals.	8) 610·2	
Mean Immersed Girth (say)	76·3	
× Length	380	
Product	28994	
× Coefficient of Augmentation	1·275	
Augmented Surface	36979	Square feet.
Indicated Horse-power on Trial	5471	
× Coefficient of Propulsion	20000	
Divide by Aug. Surface	36979)109,420,000	Product.
Cube of Probable Speed . . .	2959	
Probable Speed, computed	14·356	Knots.
Actual Speed, on Trial	14·354	
Difference . . .	·002	

This calculation is practically condensed into this:

Area of surface immersed . . . . . 28,994 square feet.

Coefficient of augmentation . . . . . $=1\cdot275$.

Then $28{,}994 \times 1\cdot275 = 36979$ square feet of augmented surface.

The indicated horse power on trial was 5471, which, multiplied by the coefficient of propulsion, $20{,}000 = 109{,}420{,}000 \div 36979 = 2959$: then, as the cube root of $2959 = 14\cdot356$

that was the calculated speed in knots per hour; and the actual speed at trial was 14·354 knots per hour, being a difference of ·002 of a knot only.

Another method in this case is to compute the proper least length of after-body for the intended speed—that is, take *three-eighths of the square of the speed in knots for the length in feet:* next—

Divide the actual length of after-body by the proper length; if the actual after-body is too short, the quotient will be a fraction less than 1; subtract the square of that fraction from 1, and extract the square root of the remainder: after that—

Multiply that square root by the mean of the squares of the sines of the obliquities of the water-lines of the after-body to a fore-and-aft line, by the area of immersed midship section in square feet, and by the constant 566; the product will be the *additional augmented surface*, to which the deficiency of the length of the after-body is equivalent; two modern examples are here given.

EXAMPLE I.—Merchant Steamer.

Intended speed, about 15 knots.
Proper length of after-body, $15^2 \times \frac{3}{8} = 84$ ft., nearly.
$\frac{\text{Actual length}}{\text{Proper length}} = \frac{60}{84} = \frac{5}{7}$; and $\sqrt{\left\{1 - \frac{5^2}{7^2}\right\}} = 0{\cdot}7$, nearly.

Mean of squares of sines of obliquities of water-lines of after-body	0·04
Immersed midship section, 61 square feet; $0{\cdot}7 \times 0{\cdot}04 \times 61 \times 566 = 967$ square feet, being the additional augmented surface equivalent to the deficiency of length of the after-body.	
Actual augmented surface . .	2982 square feet.
Add for short after-body . . .	967 „
Total . . .	3949 „
This might be called the *corrected augmented surface.*	
Computation of probable speed with the actual indicated power of .	655·5 horses.
Multiply by the ordinary coefficient of propulsion	20,000
Divide by corrected augmented surface . . . . 3949)	13,110,000 product.
Cube of probable speed . .	3320
Probable speed, by calculation .	14·918 knots.
Actual speed, by trial	15·065 „
Difference	0·147 knot;

or about 1 per cent.; and the error is on the safe side.

EXAMPLE II.—Merchant Steamer.

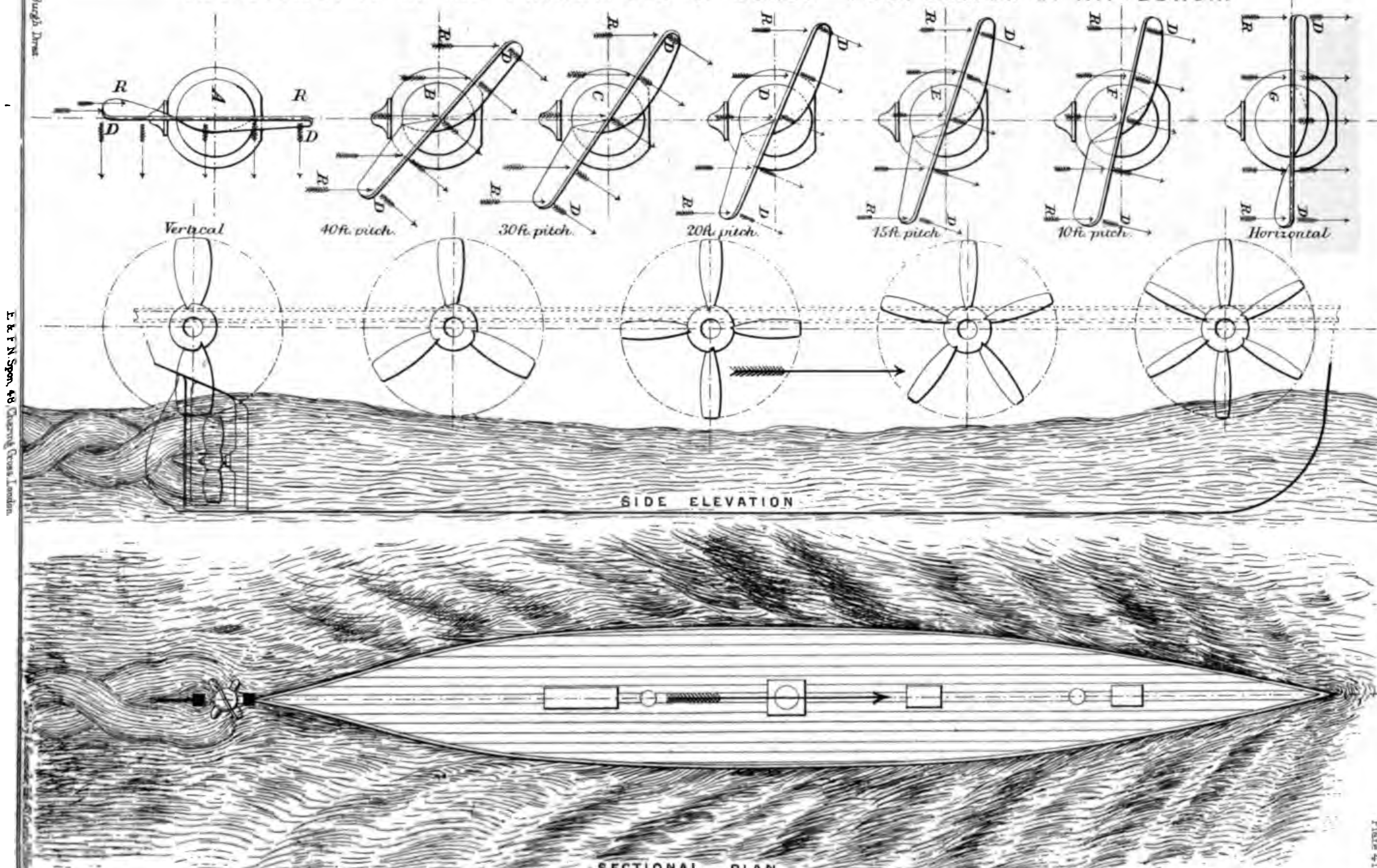
Intended speed, about $17\frac{1}{2}$ knots.
Proper length of after-body, $(17\frac{1}{2})^2 \times \frac{3}{8} = 115$ ft., nearly.
$\frac{\text{Actual length}}{\text{Proper length}} = \frac{70}{115} = 0{\cdot}61$, nearly; and $\sqrt{\{1 - ({\cdot}61)^2\}} = 0{\cdot}79$, nearly.

Mean of squares of sines of obliquities of water-lines of after-body	0·036 nearly.
Immersed midship section, 70 square feet, nearly; $0{\cdot}79 \times 0{\cdot}036 \times 70 \times 566 = 1127$ square feet, nearly; additional augmented surface.	
Actual augmented surface . .	3965 square feet.
Add for short after-body . . .	1127 „
Corrected augmented surface .	5092
Computation of probable speed, with the actual indicated power of .	1316 horses.
Multiply by the ordinary coefficient of propulsion	20,000
Divide by corrected augmented surface . . . . 5092 (	26,320,000 product.
Cube of probable speed . . .	5169
Probable speed, by calculation .	17·29 knots.
Actual speed, by trial	17·43 „
Difference	0·14 knot;

being about 0·8 per cent., and on the safe side.

Plate 41

THE GEOMETRY OF THE PRINCIPLES OF SCREW-PROPULSION BY N. P. BURGH.



N. P. Burgh Drew.

E. & F. N. Spon, 48, Charing Cross, London.

THE GEOMETRY OF THE PRINCIPLES OF SCREW-PROPULSION, BY N. P. BURGH, PLATE 41.—The utility of this Plate is to demonstrate by illustration the principles of screw-propulsion which have been explained in this work, and to point out a few novel features that have not been alluded to; it will serve also as a guide for committing to memory the *facts* that are ever coincident with screw-propulsion, for practical purposes.

ANGLES OF THE BLADES.—Messrs. Maudslay, in their article at page 162 state that "the probable action of the blades in the water when they are set at an angle unsuitable for the highest propulsion of the hull to which they are fitted is that on starting, they will strike the water sideways, or laterally disturb it, and thus disturb the aft volume also; and this side-striking will continue with a reducing effect until the speed of the hull agrees with the velocity of the propeller; when the blades will *cut* the forward current *without* disturbing either the side or aft currents. Obviously then if the angles of the blades are not in accordance with the velocity requisite for them to propel the hull at the highest speed with the least power, a great deal of the power is absorbed by the 'side striking' being continued even when the blades are revolving at the maximum velocity proportionate to the force employed. It may occur also that the actual revolving speed of the screw will be more than what is theoretically required to propel the hull at a certain lineal speed; which difference or loss is termed 'slip,' and therefore the cause for the 'slip' is that the 'side-striking' disturbs not only those currents, but also the aft volume.

"Now the aft volume is the main agent in the matter of screw-propulsion, as it is the *resistance* which the screw-blades bear against to push or propel the hull forward, and it is evident therefore that the progress of the hull will be increased with the same velocity for the propeller, if the aft volume is undisturbed; because it will then be what is termed 'dead' or 'solid' water, or of the greatest resistance to the backward thrust of the screw-blades."

It is therefore evident from those facts that the angle of the blade should be in proportion to the speed of the propeller.

The illustrations in the Plate 41 show five plans of blades and bosses of screw-propellers each 15 ft. in diameter. On the top of the Plate is a plan with the blade horizontal, and at the bottom the blade is vertical. The arrows, R R, pointed *to* the blade are the indications of the resisting properties of the water behind the blade, or the volume that receives the back pressure of the propeller. The arrows, D D, that are pointed *from* the blade depict the resisting properties of the disturbed forward water as caused by the action of the blades.

The plan A is the position of the blade when in a line with the keel, and the arrows, R R, are pointing, it will be noticed, in all cases in the same direction. Now, the arrows D D are on the front surface of the blade, and their position is *always* at right angles with

its position; so that were the blade, as in the plan A, put in motion, the ship would not move forward or backward while the *power* to turn the screw at a comparatively minimum number of revolutions would be maximum.

The diagram B shows the angle of the blade to be at 40° *with the centre line of the boss at right angles with the line of keel*, which is for a pitch of 40 ft., or 2·666 times the diameter. The arrows D D are at right angles with the blades, but the arrows R R are parallel with the line of keel as before. A propeller as this is would require a large power to drive it at a high velocity, as it closely embraces the principles of the diagram A. The diagram C is a greater contrast, as the pitch here is 30 ft., or twice the diameter of the screw, and the angle of the blade 32½°. This angle, then, being less than the one below it, the horizontal limit of the arrows, R R, is greater. Next the diagram D must be noticed; in this case the pitch is 20 ft., or the blade set at an angle of 23°, and the ratio of the pitch is 1·333 of the diameter; here the limit of the arrows R R is longer than before, on account of the angle being reduced. The diagram E partakes of a similar proportion, as the pitch in this case is equal to the diameter, or 15 ft., and the angle 18°. Above this is the diagram F, which is the plan of the blade set at an angle of 12°, or at a pitch of only 10 ft., being ·75 of the diameter; the limit of the arrows R R is the greatest in this example, because the angle of the blade is the least. A screw-propeller proportioned as this would give extreme "positive slip"—say from 40 to 60 per cent.—unless driven at a very high velocity—say from 90 to 120 revolutions. Lastly of these plans to be noticed now is G, which shows the blade exactly at right angles to that at A; and the difference in these two extreme positions results in one effect, but with two limits of power required. We stated before that the power requisite for the propeller as at A would be *maximum* with no propulsion, and we add now, that for that at G the power would be *minimum* with the same effect, as the arrows R R and D D demonstrate. Our purpose here, therefore, is to explain that the angles for the blades of screw-propellers lie between two limits, as at A and G; and the more acute the angle is with the line of keel the greater is the pitch to the diameter.

The main question next to be answered is, what is the best angle for the blades of the screw-propeller? According to the present practice the best angle ranges from 18 to 23 degrees, which results from the proportions being pitch equal diameter and pitch 1·333 times the diameter; of course the angle can always be accurately demonstrated, as the diagram, Fig. 3, in Plate 1, at page 28, illustrates; or in the absence of geometry, the angle can be known from

$$\frac{\text{Pitch.}}{\text{Circumference of diameter of screw.}} = \text{Natural tangent of the angle of the blade,}$$

and a table of natural tangents for this purpose is given in page 264.

The extreme limits of pitch are therefore from infinitely fine, in which the blade is at

The sectional plan in the Plate illustrates the form or lines of the hull at the line of flotation, and how the water is separated by the advance of the bow cutting into it, and thus causing the crests alluded to at that part. The surface of the water, it will be seen, is depicted as rolling over and over, or fold over fold—as also explained in page 4 of this work by the writer—and continuing in that state from the bow to the stern.

Now it must be distinctly understood that the *production* of this results from the bow to the midship section only; but as the ship advances, the after part moves through the water thus set in motion by the forward part; and as the ship is shown as if she were moving forward, the waves are shown as continual for the entire length of the hull, and beyond it aft.

We explain next the action of the water as caused by the revolving and advancing motion of the screw. The result from this is somewhat doubtful as a rule, because the exceptions occur according to the shape of the immersed portion of the ship and the speed of the screw. We have in the Plate shown the general action, which is that the *volume driven back by the screw* is equal to its diameter *minus that of the boss*, and is formed into a partial vortex until reaching the rudder, and when there it is divided into streams which unite when past the rudder; and resume the vortical condition.

Of course, when the rudder is at an angle the ship is turning *towards* it, and the stream caused by the propeller is divided unequally, instead of as shown. Another feature is, that the less the screw impels the water back from it, the more "hold" the rudder has to steer the ship.

Now the formation of this vortex will, of course, be subject to the number of the blades, because with the two-bladed propeller the volume set in motion by each blade is the *greatest*, while with the six-bladed propeller it is subdivided into two parts, and thus the vortex will be reduced. This reduction, however, is not always favourable for propulsion, because the two extra blades between *the two* originals cut up the water, and thus lessen the resistant property of it; but with the two blades only, the volume, although carried around by the blade, remains nearly solid while in contact with it, and thus the vortex is a resistant for the propeller to press against. The shape of the vortex lengthways is as a cork-screw whose diameter is gradually reduced to a point, and this formation is due to the surrounding volume pressing on the water put in motion by the blades. Therefore the volume gradually absorbs the force generated, and thus reduces the vortex to the common condition.

Our conclusion, therefore, on this question is, that the two-bladed propeller is the most efficient for blades of the Griffiths' shape, because the volume set in motion by them is situated midway, or central of the length of the blade from the boss to the tip, and for blades nearly approaching that shape three is the correct number, while, if using four blades, they should be of the natural form with the leading corners curved back.

TABULAR STATEMENT OF THE RATIOS OF THE PROPORTIONS OF MODERN SCREW-PROPELLERS ILLUSTRATED IN THIS WORK.

References.		Indicated horse-power.	Indicated horse-power. / Nominal horse-power.	Diameter of Propeller in feet. / Diameter of Boss in feet.	Area of the Propeller's Diameter in square feet. / Area of Blades' surface in square feet.	Nominal horse-power. / Area of Blades' surface in square feet.	Indicated horse-power. / Area of Blades' surface in square feet.	Area of one Blade in square feet. / Thickness of the Blade at root in inches.	Area of one Bla in square feet / Total Area of Securing Stud for one Blade i square inches.
Plate	Page								
18	124	6193	4·587	6·	3·326	9·92	45·536	3·4	·253
19	125	6867	5·086	5·344	3·416	9·79	49·76	3·83	·348
20	127	6000	6·	5·75	3·054	7·353	44·117	3·57	·344
16	122	2516	5·032	4·	2·827	5·5	27·956	3·75	1·25
B	17	1475	4·214	5·	3·418	6·1	25·877	2·11	Area of neck ·244
A	15	502	6·275	3·77	3·546	5·	31·375	1·96	·724
15	106	...	...	4·64	2·40	2·1	...	3·16	·622
15A	109	537	5·37	4·098	2·208	5·	26·85	2·03	·539
12	81	6705	6·705	4·181	4·350	10·47	70·209	4·34	·401
11	79	6065	6·065	3·538	4·19	10·084	61·163	4·958	·311
21	129	5092	4·073	3·645	3·769	10·416	42·433	6·03	Area of neck ·236
10	77	2871	5·742	3·6	3·742	7·5	42·22	5·66	3·207
25	138	2249	4·498	4·	3·677	7·225	32·5	5·766	Area of neck ·224
32	162	1698	4·425	5·2	5·404	9·285	4·428	3·5	Area of neck ·152
34	164	552	3·68	4·958	4·29	8·333	30·66	2·6	Area of neck ·203
13	100	317·32	3·966	4·499	4·897	6·151	24·41	2·	·441
23	136	...	...	2·614	3·668	6·640	...	1·92	·544
9	75	1772	4·43	8·	2·84	5·65	25·028	2·95	None.
C	17	458·5	5·731	4·833	2·293	4·44	25·472	1·37	None.
8	74	603	1·723	9·64	5·026	8·75	15·075	5·	None.
17	123	2400	6·	4·	2·68	5·333	32·	3·083	None.
14	102	770	4·4	4·9	2·848	5·75	25·329	1·97	None.
15B	111	13·75	2·29	7·27	2·134	2·6	5·978	·681	None.
D	20	15·366	2·561	6·	2·454	3·	7·68	·666	None.

Example 4.—D. S. T. S. S. $\frac{\text{Area of diameter} = 44{\cdot}17}{\text{constant} = 2{\cdot}208} = 20$ = area of blades' surface.

Another rule is shown in the Table also; it is: Area of blade surface =

$$\frac{\text{Nominal horse power}}{5 \text{ to } 9}$$

using the smaller number for the lowest ratio of indicated power to the nominal, as shown in the Table also.

Example 1.—"Minotaur." $\frac{\text{Nominal horse power} = 1350}{\text{constant} = 9{\cdot}92} = 136$ = area of blades' surface.

Example 2.—"Lord Warden." $\frac{\text{Nominal horse power} = 1000}{\text{constant} = 10{\cdot}47} = 95{\cdot}5$ = " "

Example 3.—"Charkieh." $\frac{\text{Nominal horse power} = 350}{\text{constant} = 6{\cdot}1} = 57$ = " "

Example 4.—D. S. T. S. S. $\frac{\text{Nominal horse power} = 100}{\text{constant} = 5} = 20$ = " "

When the area of the immersed midship section of the hull is considered in relation to the area of the blade surface, then the formula will be: Area of blade surface =

$$\frac{\text{Area of midship section}}{10 \text{ to } 8}$$

Example 1.—"Minotaur." $\frac{\text{Area of midship section} = 1322}{\text{constant} = 9{\cdot}720} = 136$ = area of blades.

Example 2.—"Warrior." $\frac{\text{Area of midship section} = 1260}{\text{constant} = 10{\cdot}5} = 120$ = " "

Example 3.—"Charkieh." $\frac{\text{Area of midship section} = 462}{\text{constant} = 8{\cdot}105} = 57$ = " "

Example 4.—"Ruahine." $\frac{\text{Area of midship section} = 424}{\text{constant} = 13{\cdot}947} = 30{\cdot}4$ = " "

These constants are taken from practice in the Royal and Merchant Navies, where the engines indicated from 6 to 4·5 of the nominal horse power, and the speed of the ships was from 14 to 15 knots per hour.

Thickness of the Blade at the Root.—The material, length, and area of the blade determine this in all cases; but as the area of the blade is subject to its length in particular, the latter limit is dispensed with in this formula, and the area only considered; therefore the thickness of the blade at the root in inches =

$$\frac{\text{Area of blade in feet}}{4 \text{ to } 2,}$$

the higher constant being for wrought iron and gun-metal, and the lesser for cast iron.

Example 1.—"Minotaur." $\dfrac{\text{Area of blade} = 34}{\text{constant} = 3{\cdot}4} = 10 =$ thickness at root.

Example 2.—"Lord Warden." $\dfrac{\text{Area of blade} = 47{\cdot}75}{\text{constant} = 4{\cdot}34} = 11 =$ " "

Example 3.—"Charkieh." $\dfrac{\text{Area of blade} = 9{\cdot}5}{\text{constant} = 2{\cdot}11} = 4{\cdot}5 =$ " "

Example 4.—D. S. T. S. S. $\dfrac{\text{Area of blade} = 6{\cdot}67}{\text{constant} = 2{\cdot}03} = 3{\cdot}25 =$ " "

Total Area of the Securing Studs for each Blade.—This depends in some measure on the diameter of the blade-flange, but from the examples illustrated in this work and the Table on page 260, the area of the securing studs in square inches for each blade =

$$\frac{\text{Area of the blade in square feet}}{{\cdot}313 \text{ to } {\cdot}457}$$

using the lesser decimal constant for the narrow blades, and the greater for wide short blades, as will be seen from the Plates.

Example 1.—"Minotaur." $\dfrac{\text{Area of blade} = 34}{\text{constant} = {\cdot}253} = 134{\cdot}425 =$ area of studs in inches.

Example 2.—"Lord Warden." $\dfrac{\text{Area of blade} = 47{\cdot}75}{\text{constant} = {\cdot}409} = 153{\cdot}936 =$ " "

Example 3.—"Charkieh." $\dfrac{\text{Area of blade} = 9{\cdot}5}{\text{constant} = {\cdot}244} = 38{\cdot}484 =$ " "

Example 4.—D. S. T. S. S. $\dfrac{\text{Area of blade} = 6{\cdot}67}{\text{constant} = {\cdot}539} = 12{\cdot}369 =$ " "

Of course, as all the constants given in the preceding rules are taken from past practice, and as the circumstances are expressed, any future practice embracing those circumstances will give similar results as before; and for that reason the Tables commencing at page 231 must always be alluded to for the detail matter and the Plates for the shape and application; indeed the information is so complete that a screw-propeller of any size and form can be correctly designed from the examples illustrated and tabulated. In applying the constants for exceptional practice, care must be taken to remember the attendant facts so as to act in accordance with them; but taking the constants in round numbers for general use, or as an approximation on the safe side for sufficient strength, they are practically correct. The factors for safety, therein coincident, range from 8 to 10 as the general practice; while in some cases 12 has been used as a multiplier, above the breaking strain of the material applied.

The following Table will be a guide for a conclusion as to the proportion of the engine power to the diameter of the screw-propeller according to the present practice.

TABLE OF THE PROPORTIONS OF THE ENGINE POWER TO THE DIAMETERS OF THE SCREW-PROPELLERS, ILLUSTRATED IN THIS WORK.

Reference Numbers.		Nominal horse-power. Diameter of Screw-propeller in feet.	Indicated horse-power. Diameter of Screw-propeller in feet.	Reference Numbers.		Nominal horse-power. Diameter of Screw-propeller in feet.	Indicated horse-power. Diameter of Screw-propeller in feet.
Plate	Page			Plate	Page		
18	124	56·25	258·041	25	138	27·778	124·945
19	125	55·102	280·28	32	162	23·529	99·882
20	127	43·478	260·87	34	164	15·12	55·65
16	122	27·8	139·78	13	100	8·89	35·257
B	17	22·23	93·65	23	136	8·334	...
A	15	9·412	59·058	9	75	25·	110·75
15	106	12·5	...	C	17	11·034	63·241
15A	109	13·3	71·602	8	74	21·875	37·6875
12	81	43·478	291·521	17	123	25·	150·
11	79	43·478	263·7	14	102	16·6	73·34
21	129	52·083	212·167	15B	111	2·4	5·5
10	77	27·778	159·5	D	20	2·4	61·44

TO DETERMINE THE ANGLE OF THE BLADE WHEN THE PITCH AND THE DIAMETER OF THE SCREW-PROPELLER ARE KNOWN.

The angle of the blade of any screw-propeller is coincident with the *natural* tangent of the arc of the circle of the circumference of the screw's diameter; hence this rule: Angle of the blade $= \dfrac{\text{pitch}}{\text{circumference of the diameter}} =$ natural tangent in relation to the angle.

And from this Table of natural tangents the angle can be known.

TABLE OF THE ANGLES OF BLADES THAT ARE COINCIDENT WITH THE NATURAL TANGENTS GIVEN.

Angle of Blade in degrees.	Natural Tangent.	Angle of Blade in degrees	Natural Tangent.	Angle of Blade in degrees.	Natural Tangent.	Angle of Blade in degrees.	Natural Tangent.	Angle of Blade in degrees.	Natural Tangent.	Angle of Blade in degrees.	Natural Tangent.
1	·01745	9	·15838	17	·30573	25	·46630	33	·64940	40	·83909
2	·03492	10	·17632	18	·32491	26	·48773	34	·67450	41	·86928
3	·05240	11	·19438	19	·34432	27	·50952	35	·70020	42	·90040
4	·06992	12	·21255	20	·36397	28	·53170	36	·72654	43	·93251
5	·08748	13	·23086	21	·38386	29	·55430	37	·75355	44	·96568
6	·10510	14	·24932	22	·40402	30	·57735	38	·78128	45	1·00000
7	·12278	15	·26794	23	·42447	31	·60086	39	·80978		
8	·14054	16	·28674	24	·44522	32	·62486				

Example 1.—"Warrior."—Screw-propeller 24 ft. in diameter, pitch 30 ft. and—$24 \times 3{\cdot}1416 = 75{\cdot}398 =$ circumference; then $\dfrac{30{\cdot}0000}{75{\cdot}398} = {\cdot}3978$, the natural tangent in relation to the angle of 22° nearly, or 21° 40′, which is the angle of the blade of the "Warrior's" screw-propeller.

Example 2.—"Minotaur."—Screw-propeller 24 ft. in diameter, pitch 25 ft., and 75·398 = circumference; then $\frac{25\cdot0000}{75\cdot398} = \cdot3315$, the natural tangent in relation to the angle 18°·5 nearly, or 18° 28′ which is the angle of the blade of the "Minotaur's" screw-propeller.

To determine the Pitch when the Diameter of the Screw and the Angle of the Blade are given.—This problem is exactly the reverse of that preceding it, so that to determine the pitch when the angle is known $= \frac{\text{Circumference of the screw's diameter}}{\text{natural tangent in relation to the angle}}$.

Table of the Proportions of the Length of the Blades on the line of Keel to the Pitch, of the Modern Screw-propellers Illustrated in this Work.

References,		Pitch in feet. / Length of Blade in feet on line of Keel.	References.		Pitch in feet. / Length of Blade in feet on line of Keel.	References.		Pitch in feet. / Length of Blade in feet on line of Keel.	References.		Pitch in feet. / Length of Blade in feet on line of Keel.
Plate	Page		Plate	Page		Plate	Page		Plate	Page	
18	124	12·75	15	106	6·66	25	138	5·085	C	17	5·66
19	125	13·25	15A	109	6	32	162	7·9	8	74	6
20	127	13·63	12	81	5·529	34	164	...	17	123	6·09
16	122	5·939	11	79	4·947	13	100	9·931	14	102	6·76
B	17	19·5	21	129	6	23	136	6·208	15B	111	8·
A	15	4·313	10	77	5·372	9	75	6·519	D	20	12·96

General Rules for common Screw-propellers.—Diameter of the screw of course is due to the depth of immersion of the vessel at the stern; the extremity of the blade should be immersed $\frac{1}{10}$ of its diameter, as a guide for setting out the proportions, but practical demonstration proves that in a heavy sea this rule is often deviated from, according to the susceptibility of the vessel to the action which is enforced by the sea. The following rules are deduced from practice, consequently may be relied on:

Diameter of screw = stroke of engine × 6 to 5.

Pitch = diameter × 1·5 to 1·25 to 1 for quick speeds.

Length of blade on line of keel $= \frac{\text{pitch of screw}}{\text{For 2 blades 5 to 6, for 3 blades 7 to 8, for 4 blades 9 to 12, for 5 blades 14 to 15, for 6 blades 16 to 19.}}$

Diameter of forward bearing = diameter of crank shaft × 1·25 as a minimum.

Diameter of boss = diameter of crank shaft × 2 as a minimum.

Width of **T** coupling = diameter of shaft × ·75

Diameter of **T** coupling $= \frac{\text{diameter of screw}}{5 \text{ to } 6}$

Thickness of blade at the root = 2 inches for a screw 4 feet in diameter, increasing from this $\frac{1}{8}$ of an inch per foot for gun-metal.

Thickness of blade at the tip $= \frac{\text{thickness at root}}{3 \text{ to } 4}$

$$\text{Theoretical speed of ship in knots per hour} = \frac{\text{speed of screw in feet per hour}}{6080 = \text{Admiralty knot in feet}}$$

Loss of speed or slip of screw = theoretical speed of ship minus actual speed of ship.

Actual speed of ship = speed of screw minus slip.

To ascertain the actual pitch required at a given speed of the screw, to produce a given speed of the ship, the rule will be as follows :

$$\text{Pitch of screw in feet} = \frac{\text{actual speed of ship in feet per hour}}{\text{number of revolutions of screw per hour} \times {}^{\cdot}9 \text{ to } {}^{\cdot}75}$$

This rule allows a slip or loss of speed of 10 to 25 per cent., 20 per cent. being the average for war ships.

The following Table of the nominal horse power requisite for screws of given diameters, is deduced from the best results of the present day:

Nominal horse-power collectively.	Diameter of Screw.		Pitch—Variable.					Nominal horse-power per foot of Screw's diameter.	Nominal horse-power collectively.	Diameter of Screw.		Pitch—Variable.					Nominal horse-power per foot of Screw's diameter.
	Ft.	In.	Ft.	In.		Ft.	In.			Ft.	In.	Ft.	In.		Ft.	In.	
40	5	0	6	0	to	7	6	8·0	500	18	0	19	6	to	24	6	27·77
60	6	0	7	6	„	9	0	10·0	600	18	6	20	0	„	25	0	32·43
100	8	0	10	0	„	12	0	12·5	800	19	0	20	6	„	27	6	42·1
150	10	0	12	0	„	15	0	15·0	900	20	0	20	0	„	30	0	45·0
200	11	0	13	6	„	18	6	18·18	1000	21	0	21	0	„	32	0	47·61
300	14	0	16	6	„	21	6	21·42	1250	23	0	21	0	„	26	0	54·34
400	16	0	18	0	„	24	0	25·0	1350	24	0	22	0	„	26	0	56·25

Rules for the Griffiths' Screw-propeller :

$$\text{Diameter of boss} = \frac{\text{diameter of screw}}{3 \text{ to } 4}$$

Length of boss = diameter of flange + $\frac{1}{2}$ diameter of shank, in modern cases equal to the diameter of boss and diameter $\times$ ·75 to ·86.

Diameter of flange of blade = diameter of boss $\times$ ·5.

$$\text{Thickness of flange at edge} = \frac{\text{diameter}}{20}$$

Lap of blade on boss beyond flange = $\frac{3}{4}$ of an inch per foot of diameter of screw.

$$\text{Width of blade at widest part} = \frac{\text{diameter of screw}}{3}$$

$$\text{Width of blade at point} = \frac{\text{diameter of screw}}{7}$$

Thickness of blade at root = $\frac{1}{3}$ to $\frac{1}{2}$ of an inch to each foot's diameter.

Thickness at point = $\frac{1}{6}$ of that at root.

Diameter of shank = diameter of boss × ·25.

Metal around shank $= \dfrac{\text{diameter of boss}}{23 \text{ to } 24}$

Metal beyond flange and cotter $= \frac{7}{12}$ of depth of cotter.

Width of main cotter = diameter of shank × ·5.

Thickness of main cotter $= \dfrac{\text{diameter of shank}}{6}$

Thickness of feathers in boss $= \dfrac{\text{diameter of boss}}{40}$

Width of small cotter $= \dfrac{\text{diameter of boss}}{20}$

Thickness of small cotter $= \dfrac{\text{width}}{2}$

Angle in side of wedge box = $7\frac{1}{2}$ degrees.

Metal in cheeks where cotters enter $= \dfrac{\text{diameter of boss}}{40}$

Thickness of plate over wedges $= \dfrac{\text{diameter of boss}}{48}$

TABLES OF THE PROPORTIONS OF GRIFFITHS' SCREW-PROPELLERS.

Diameter of Screw.	Diameter of Boss.	Length of Boss.	Lap of Blade on Boss beyond Flange.	Width of Blade at widest part.	Width of Blade at point.	Thickness of Blade at root.	Thickness of Blade at point.	Diameter of Flange of Blade.	Thickness of Flange of Blade.
Feet.	Ft. In.	Ft. In.	Inches.	Ft. In.	Ft. In.	Inches.	Inches.	Ft. In.	Inches.
6	1 9	1 $1\frac{1}{8}$	$4\frac{1}{2}$	2 0	0 $10\frac{1}{4}$	2	$\frac{5}{16}$	$10\frac{1}{2}$	$\frac{1}{2}$
7	2 0	1 3	$5\frac{1}{4}$	2 4	1 0	$2\frac{5}{16}$	$\frac{3}{8}$	12	$\frac{5}{8}$
8	2 3	1 $4\frac{7}{8}$	6	2 8	1 $1\frac{3}{4}$	$2\frac{5}{8}$	$\frac{7}{16}$	1 $1\frac{1}{2}$	$\frac{11}{16}$
9	2 6	1 $6\frac{3}{4}$	$6\frac{3}{4}$	3 0	1 $3\frac{3}{8}$	3	$\frac{1}{2}$	1 3	$\frac{3}{4}$
10	2 9	1 $8\frac{5}{8}$	$7\frac{1}{2}$	3 4	1 $5\frac{1}{8}$	$3\frac{1}{4}$	$\frac{9}{16}$	1 $4\frac{1}{2}$	$\frac{13}{16}$
11	3 0	1 $10\frac{1}{2}$	$8\frac{1}{4}$	3 8	1 7	$3\frac{5}{8}$	$\frac{5}{8}$	1 6	$\frac{7}{8}$
12	3 6	2 $2\frac{1}{4}$	9	4 0	1 $8\frac{1}{2}$	4	$\frac{11}{16}$	1 9	$1\frac{1}{16}$
13	3 6	2 $2\frac{1}{4}$	$9\frac{3}{4}$	4 4	1 $10\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{4}$	1 9	$1\frac{1}{8}$
14	4 0	2 6	$10\frac{1}{2}$	4 8	2 0	$4\frac{5}{8}$	$\frac{13}{16}$	2 0	$1\frac{3}{16}$
15	4 0	2 6	$11\frac{1}{4}$	5 0	2 $1\frac{3}{4}$	5	$\frac{7}{8}$	2 0	$1\frac{3}{16}$
16	4 3	2 $7\frac{7}{8}$	12	5 4	2 $3\frac{5}{8}$	$5\frac{1}{4}$	$\frac{15}{16}$	2 $1\frac{1}{2}$	$1\frac{1}{4}$
17	4 6	2 $9\frac{3}{4}$	$12\frac{3}{4}$	5 8	2 $5\frac{1}{8}$	$5\frac{5}{8}$	$\frac{15}{16}$	2 3	$1\frac{3}{8}$
18	5 0	3 $0\frac{1}{2}$	$13\frac{1}{2}$	6 0	2 $6\frac{7}{8}$	6	1	2 6	$1\frac{1}{2}$
19	5 0	3 $0\frac{1}{2}$	$14\frac{1}{4}$	6 4	2 $8\frac{1}{2}$	$6\frac{1}{4}$	$1\frac{1}{16}$	2 6	$1\frac{1}{2}$
20	5 6	3 $5\frac{1}{8}$	15	6 8	2 $10\frac{1}{4}$	$6\frac{5}{8}$	$1\frac{1}{16}$	2 9	$1\frac{5}{8}$
21	5 6	3 $5\frac{1}{8}$	$15\frac{3}{4}$	7 0	3 0	7	$1\frac{1}{8}$	2 9	$1\frac{5}{8}$
22	6 0	3 9	$16\frac{1}{2}$	7 4	3 $1\frac{3}{4}$	$7\frac{5}{8}$	$1\frac{1}{4}$	3 0	$1\frac{13}{16}$
23	6 0	3 9	$17\frac{1}{4}$	7 8	3 $3\frac{3}{8}$	$7\frac{1}{4}$	$1\frac{5}{16}$	3 0	$1\frac{7}{8}$
24	6 6	4 $0\frac{5}{8}$	18	8 0	3 $5\frac{1}{8}$	8	$1\frac{3}{8}$	3 3	$1\frac{15}{16}$

TABLE OF THE PROPORTIONS OF GRIFFITHS' SCREW-PROPELLERS.

Diameter of Screw.	Diameter of Shank of Blade.	Metal round Shank.	Metal between Flange and top of Cotter.	Width of Main Cotter.	Thickness of Main Cotter.	Thickness of Feather in Boss.	Width of small Cotter.	Thickness of small Cotter.	Metal in Cheek which Cotter enters.	Thickness of Plate over Wedges.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
6	$5\frac{1}{4}$	$\frac{7}{8}$	$1\frac{1}{4}$	$2\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$
7	6	1	$1\frac{3}{4}$	3	1	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
8	$6\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{15}{16}$	$3\frac{3}{8}$	$1\frac{1}{8}$	$\frac{11}{16}$	$1\frac{3}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{9}{16}$
9	$7\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{3}{16}$	$3\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$
10	$8\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{8}$	$4\frac{1}{8}$	$1\frac{3}{8}$	$\frac{13}{16}$	$1\frac{5}{8}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{11}{16}$
11	9	$1\frac{1}{2}$	$2\frac{5}{8}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{3}{4}$
12	$10\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{16}$	$2\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{1}{16}$	$\frac{7}{8}$
13	11	$1\frac{3}{4}$	$3\frac{1}{8}$	$5\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$
14	12	2	$3\frac{1}{2}$	6	2	$1\frac{3}{16}$	$2\frac{3}{8}$	$1\frac{3}{16}$	$1\frac{3}{16}$	1
15	12	2	$3\frac{1}{2}$	6	2	$1\frac{3}{16}$	$2\frac{1}{2}$	$1\frac{3}{16}$	$1\frac{3}{16}$	1
16	$12\frac{3}{4}$	$2\frac{1}{8}$	$3\frac{15}{16}$	$6\frac{3}{8}$	$2\frac{1}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{16}$
17	14	$2\frac{1}{4}$	4	$6\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$
18	15	$2\frac{1}{2}$	$4\frac{3}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
19	15	$2\frac{1}{2}$	$4\frac{3}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
20	$16\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$8\frac{1}{8}$	$2\frac{13}{16}$	$1\frac{5}{8}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$
21	17	$2\frac{3}{4}$	$4\frac{3}{4}$	$8\frac{1}{2}$	$2\frac{7}{8}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{3}{8}$
22	18	3	$5\frac{1}{4}$	9	3	$1\frac{13}{16}$	$3\frac{5}{8}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$1\frac{1}{2}$
23	$18\frac{1}{2}$	3	$5\frac{1}{4}$	$9\frac{1}{8}$	$3\frac{1}{16}$	$1\frac{7}{8}$	$3\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{1}{2}$
24	$19\frac{1}{4}$	$3\frac{1}{4}$	$5\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{5}{16}$	$1\frac{15}{16}$	$3\frac{7}{8}$	$1\frac{15}{16}$	$1\frac{15}{16}$	$1\frac{5}{8}$

TABULAR STATEMENT OF THE PARTICULARS THAT ESPECIALLY RELATE TO THE POWER AND SPEED OF TWO MERCHANT MAIL SHIPS, ONE BEING FITTED WITH A SIX-BLADED SCREW-PROPELLER, AND THE OTHER WITH TWIN THREE-BLADED SCREW-PROPELLERS, BY MESSRS. RENNIE AND MESSRS. DUDGEON.

Name of Ship.	Displacement in tons.	Area of Mid-ship Section in square feet	Indicated Horse-power of Engines.	$\frac{\text{Indicated Horse-power.}}{\text{Area of Mid-section.}}$	$\frac{\text{Displacement in tons.}}{\text{Indicated Horse-power.}}$	Speed in Knots per hour.	$\frac{\text{Area of Midship Section in sq. ft.}}{\text{Total Area of Propelling Surface in square feet.}}$	$\frac{\text{Speed}^3 \times \text{Mid-section.}}{\text{Indicated Horse-power.}}$	$\frac{\text{Speed}^3 \times \sqrt[3]{\text{displacement}^2}}{\text{Indicated Horse-power.}}$
"Charkieh."	2200	462	1475	3·192	1·491	11·4	8·105	459·303	169·9
"Ruahine."	1850	424	1540	3·632	1·2	13	10·408	604·88	215·4

REMARKS.—The Propeller fitted to the Steam-ship "Charkieh" is illustrated by Plate B, at page 17, and the Steam-ship "Ruahine's" Propeller by Plate 14 at page 102.

TABULAR STATEMENT OF THE PARTICULARS THAT ESPECIALLY RELATE TO THE INDICATED POWER AND THE SPEED OF FOUR MODERN IRON-CLAD SHIPS IN THE ROYAL NAVY, ENGINED BY MESSRS. PENN AND MESSRS. MAUDSLAY.

Name of Ship.	Displacement in tons.	Area of Midship Section in square ft.	Indicated Horse-power of Engines.	Indicated Horse-power. / Area of Midship section.	Displacement in tons. / Indicated Horse-power.	Speed in Knots per hour.	Area of Midship Section in sq. ft. / Total Area of Propelling Surface in square feet.	Speed^3 × Mid-section. / Indicated Horse-power.	$\frac{\text{Speed}^3 \times \sqrt[3]{\text{displacement}^2}}{\text{Indicated Horse-power.}}$
H.M.S.									
"Minotaur."	10275	1322	6193	4·684	1·659	14·165	9·713	606·718	216·616
"Agincourt."	9000	1187	6867	5·785	1·3106	15·433	8·6	635·381	231·242
"Warrior."	9214	1260	5092	4·041	1·809	13·936	10·5	669·72	232·809
"Bellerophon"	7369	1207	6199	5·135	1·1818	14·053		540·371	169·229

REMARKS.—The "Minotaur's" and "Agincourt's" Propellers are shown by Plates 18 and 19, at pages 124 and 125, and the "Warrior's" by Plate 21 at page 129. The "Bellerophon's" Propeller is a two-bladed Griffiths, 23 ft. 6 in. in diameter, and set at a pitch of 20 ft. 1 in., and fitted by Messrs. Penn.

RULE FOR THE COEFFICIENT OF PERFORMANCE OF A STEAM-SHIP IN RELATION TO THE MIDSHIP SECTION.—The cube of the speed in knots per hour, multiplied by the area in feet of the immersed midship section of the ship, and divided by the indicated horse-power = the coefficient of the performance.

RULE FOR THE COEFFICIENT OF PERFORMANCE OF A STEAM-SHIP IN RELATION TO THE DISPLACEMENT.—The cube of the speed in knots per hour, multiplied by the cube root of the square of the displacement in tons of the ship, and divided by the indicated horse-power = the coefficient of performance. Or either use this rule:

The square of the cube root of the displacement, multiplied by the cube of the speed, and divided by the indicated horse power = the coefficient of the ship's performance.

The two coefficients can be seen from the Tables on this and the preceding page; their sums in general are $= \dfrac{\text{speed}^3 \times \text{mid section}}{\text{indicated horse-power}} = 500$ to 650, and in some cases as low as 450 and as high as 700. And from the $\dfrac{\text{speed}^3 \times \sqrt[3]{\text{displacement}}}{\text{indicated horse-power}} = 200$ to 220, and in some cases as low as 150 and as high as 300.

To obtain a mean coefficient of the two results, add them together and divide by 2.

RULE FOR THE INDICATED HORSE-POWER TO PROPEL A SHIP WHEN THE SPEED, DISPLACEMENT IN TONS, AND AREA OF THE IMMERSED MIDSHIP-SECTION ARE GIVEN.

$$\frac{\left[\dfrac{\text{Speed}^3 \times \text{mid-section}}{\text{coefficient.}}\right] + \left[\dfrac{\text{Speed}^3 \times \sqrt[3]{\text{displacement}^2}}{\text{coefficient.}}\right]}{2}$$

Rule for the Speed of the Ship when the Displacement in tons, Area of Midship Section, and Indicated Horse-power are given.

$$\frac{\left[\sqrt[3]{\frac{\text{Coefficient of midship-section}\times\text{Indicated horse-power}}{\text{Area of mid-section.}}}\right]+\left[\sqrt[3]{\frac{\text{Coefficient of displacement}\times\text{Indicated horse-hower}}{\text{Coefficient of displacement}}}\right]}{2}$$

Rule for the Area of the Blades of the Screw-propeller when the two preceding Rules are applied.

$$\frac{\text{Area of immersed midship-section.}}{\text{8·6 to 9 for 2 blades, 9·5 to 10 for 3 blades and 4 blades, and 10 to 10·5 for 5 and 6 blades.}}$$

The area of blades with twin-screws is less than for single screws to about 4 to 6 per cent.

Table of the Leading Particulars concerning the Speed of the Ships Engined by Messrs. Maudslay, Sons, and Field.

	Name of Ship.	Length.		Breadth.		Tonnage, B. M.	Displacement in tons.	Mean Draft.		Area of Midship Section immersed.	Total Acting Area of Propeller Blades.	Diameter of Propeller.		Pitch set at.		Indicated Horse-power.	No. of Revolutions of the Screw per minute.	Speed of the Ship in knots per hour.
		Ft.	In.	Ft.	In.			Ft.	In.		Ft.	Ft.	In.	Ft.	In.			
1	" Octavia."	252	4	52	6	3142	...	19	$5\frac{1}{4}$	...	56	18	0	20	0	2264	69·5	12·251
2	" Royal Alfred."	273	0	58	5	4045	...	24	8	...	96	19	0	27	6	3703	60·83	12·528
3	" Prince Consort."	273	0	58	5	4045	...	...		...	96	21	0	27	6	4234	56·5	13·119
4	" Agincourt."	400	0	59	3	6621	9000	24	2	1187	138	24	6	23	3	6867	61·5	15·433
5	" Affondatore."	295	0	40	0	2306	...	20	5	...	72	18	0	21	6	3666	66·	12·863
6	" Lord Warden."	280	0	58	9	4067	...	25	8	...	115	23	0	21	$4\frac{1}{4}$	6705	63·327	13·496
7	" Penelope."	266	0	50	0	3076	...	16	6	...	60	Twin screw 14	0	15	6	4702	103	12·76
8	"König Wilhelm."	356	0	60	0	6127	9600	25	6	1313	115	23	0	22	6	8344	64·	14·71
9	" Rostoff."	258	0	33	0	...	2800	17	$2\frac{1}{2}$	510	40	13	0	17	0	606	62·125	8·74
10	" Sirius."	212	0	36	0	1268	...	13	11	...	35	15	0	15	6	2293	98·21	13·263

Remarks, as to the form, No. of Blades, and type of Propeller.

1. Two-bladed Griffiths' Screw.
2. Two-bladed " "
3. Four-bladed Screw with increasing Pitch.
4. Four-bladed " " "
5. Four-bladed " " "
6. Four-bladed Screw with increasing Pitch.
7. Two-bladed Griffiths' Screw.
8. Four-bladed Screw with increasing Pitch.
9. Three-bladed " " "
10. Two-bladed Griffiths' Screw.

Table of the Leading Particulars concerning the Speed of the Ships Engined by Messrs. Penn and Son.

	Name of Ship.	Length. Ft.	In.	Breadth. Ft.	In.	Tonnage, B.M.	Displacement in tons.	Mean Draft. Ft.	In.	Area of Midship Section. Sq. Ft.	Total Acting Area of Propeller Blades. Sq. Ft.	Diameter of Propeller. Ft.	In.	Pitch set at. Ft.	In.	Indicated Horse-power.	No. of Revolutions of the Screw per minute.	Speed of the Ship in Knots per hour.
1	"Great Britain."	289	0	51	0	3500	2970 At 16 ft. draft.	19	0	689	70	16	0	19	6	1450	20 Engines. 60 Screw.	11·
2	"Himalaya."	340	5	46	$1\frac{3}{4}$	3504	3350	17	2	574	77	18	0	28	0	2105	$57\frac{1}{2}$	13·87
3	"Krön Prinz."	286	0	50	0	3404	5600	23	6	1024	83	21	4	23	6	4868	69	14·25
4	"Independencia."	215	0	44	6	2004	2960	20	9	760	60	18	0	24	0	2208	60	11·98
5	"Victoria."	316	0	57	0	4862	6674	24	2	980	70	20	0	28	0	4246	66	13·716
6	"Arapiles."	279	4	54	0	3546	4789	22	3	827	70	19	0	29	0	3236	58	12·7
7	"Arminius."	200	0	35	8	1230	1670	13	$10\frac{1}{2}$	436 Foul bottom.	35	13	0	17	6	1367	87	11·263
8	"Beherë."	260	0	35	0	1558	1700	15	$1\frac{1}{2}$	426	72	15	10	17	0	1700 Maximum.	78	13·398
9	"Lazareff."	260	0	35	9	1650	3220	20	2	635	69	13	6	19	0	780	63	9·78
10	"John Penn."	140	0	22	6	340	365	6	0	125	16 For two screws.	5	0	8	6	335	176	9·92

Remarks, as to the form, No. of Blades, and type of Propeller.

1. Two-bladed Common.
2. Two-bladed „
3. Two-bladed Griffiths'.
4. Two-bladed „
5. Two-bladed „ Wrought-iron Blades.
6. Two-bladed Griffiths'.
7. Two-bladed „
8. Four-bladed Mangin.
9. Three-bladed Common.
10. Common, twin screw.

Rules applicable to Feathering Paddles working in undisturbed water.—To determine the proper area of a pair of feathering floats for the paddle-wheels of a given vessel, to be driven at a given speed, with a given slip, the paddles working in water that is not sensibly disturbed by the ship.

Calculate according to the principles explained in page 252, the probable resistance of the ship at the intended speed.

Divide that resistance by the intended speed of the centres of the paddle-floats relatively to the water (or slip), by their intended speed relatively to the vessel (or sum of the speed of the vessel and the slip), and by the mass of a cubic foot of water, viz.—for resistance in lbs., and velocities in feet per second, 2; and for resistance in lbs., and velocities in knots, $5\frac{2}{3}$.

The quotient will be the required area in square feet.

To solve the same question, when the vessel is so proportioned that her resistance depends on her "augmented surface" only.

Divide the augmented surface by the ratio which the intended slip bears to the intended speed of the vessel, by the ratio which the intended speed of the centres of the floats bears to the intended speed of the vessel, and by the constant 566: the quotient will be the area required.

In different states of the ship's bottom the constant divisor may have different values, which, in the present state of our experimental knowledge, may be taken as ranging between 500 and 600.

EXAMPLE (from the steamer "*Admiral.*")

Augmented surface	. 8560 square feet.
Intended ratio of slip to speed of vessel	. 0·28
Intended ratio of speed of centres of floats to speed of vessel . .	. 1·28

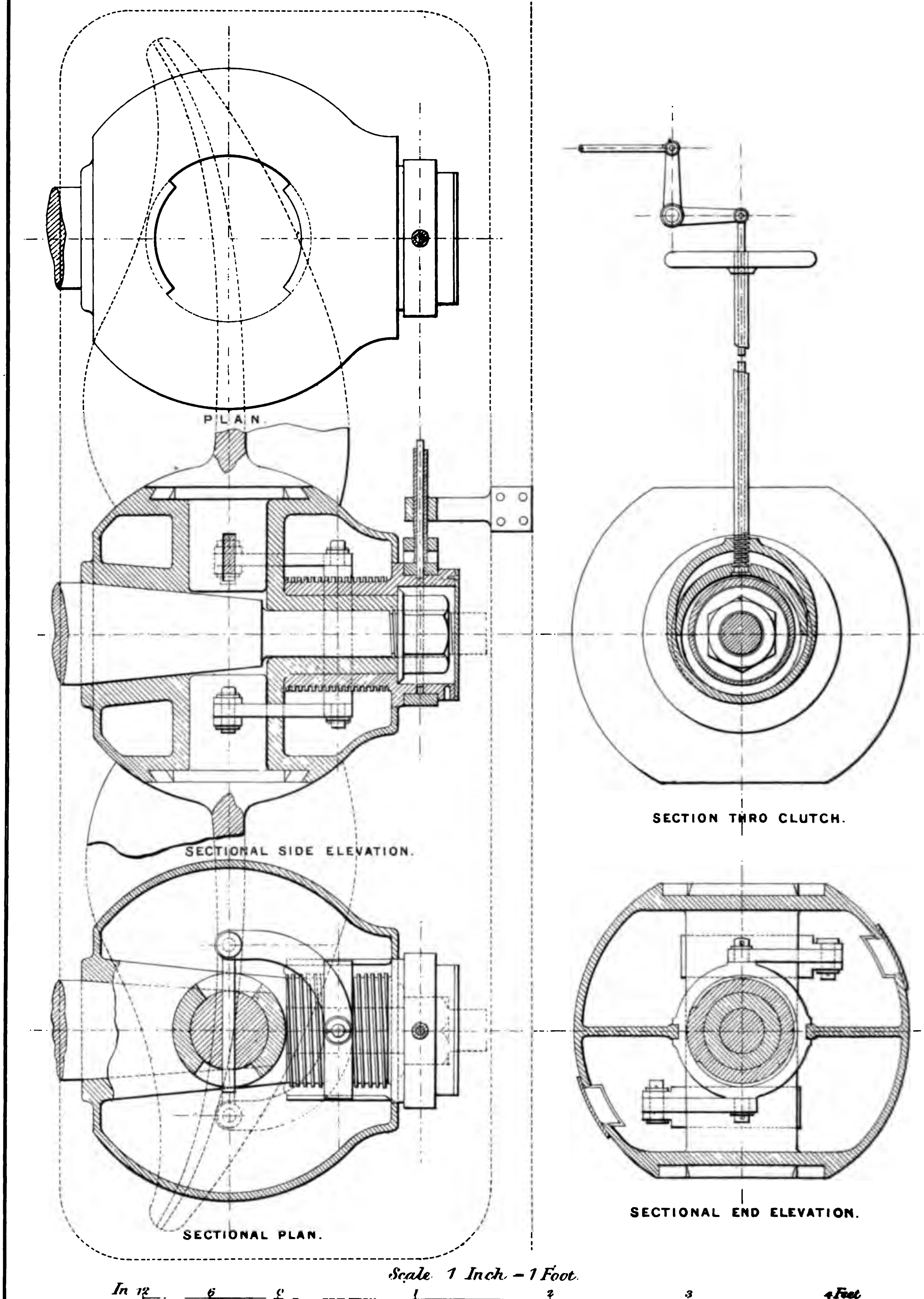
$\frac{8560}{0{\cdot}28 \times 1{\cdot}28 \times 566} = 42$ square feet, required area of a pair of floats; giving 21 square feet for a single float. The actual floats measured 7 feet broad and 3 feet deep.

RULE TO FIND THE POWER REQUIRED TO DRIVE THE PADDLES.—Multiply the estimated resistance of the vessels in lbs. at her intended speed, by the speed of the paddle-floats relatively to the vessel (that is, by the speed of the vessel plus the slip), in feet per second; this will give the required power in foot-lbs. per second, *exclusive of friction.* To include friction of mechanism, from 0·25 to 0·30 of the power exclusive of friction, may be added: the sum will be the required *indicated power* of the engines.—*Rankine.*

TABLE FOR FEATHERING PADDLES.

Ratios of Slip to—		Ratio of Speed of Paddles × Slip to Square of Speed of Ship.	Efficiency of Paddles, neglecting Friction.	Ratio of Augmented Surface of Vessel to Area of a Pair of Floats.	
Speed of Ship.	Speed of Paddles.				
0·100	0·091	0·1100	0·909	62	
0·125	0·111	0·1406	0·888	80	
0·150	0·130	0·1725	0·870	98	Ordinary limits of practice.
0·175	0·149	0·2056	0·851	116	
0·200	0·167	0·2400	0·833	136	
0·225	0·184	0·2756	0·816	156	
0·250	0·200	0·3125	0·800	177	
0·275	0·216	0·3506	0·784	198	
0·300	0·231	0·3900	0·769	221	
0·325	0·245	0·4306	0·755	244	
0·350	0·259	0·4725	0·741	267	
0·375	0·273	0·5156	0·727	292	
0·400	0·286	0·5600	0·714	317	
0·425	0·298	0·6056	0·702	343	
0·450	0·310	0·6525	0·690	3[illegible]9	
0·475	0·322	0·7006	0·678	397	
0·500	0·333	0·7500	0·667	425	

FEATHERING SCREW PROPELLER BY Mr. R. GRIFFITHS.



N.P. Burgh. Del.

E. & F. N. Spon 48 Charing Cross London.

AN APPENDIX TO CHAPTER XV.

FEATHERING SCREW-PROPELLER.

BY MR. ROBERT GRIFFITHS.

THIS arrangement is illustrated by Plate L, and consists of a method by which the blades of any screw-propeller can be made to set at any fixed position that is required to offer the least resistance to the passage of a vessel when under sail only, and also to set the blades at the most convenient angle for the propulsion of the ship.

To effect those attainments, the blades of the propeller are formed separately from the boss, with shanks, or necks at the flange, which are inserted into corresponding sockets cast with the boss. And thus the blades can be turned on their seats from an angle or "pitch," suitable for propulsion, or in a line with the keel. This movement or "turning" of the blades is produced by keys that are inserted through the sockets and shanks; and thus connects them together in one direction; the keys also project through apertures in the sockets at opposite sides, and those apertures are so formed as to allow for the partial rotation of the shanks, so that the blades can be set from the greatest angle to the position in a line with the keel.

These keys of course secure the blades also, but to make that matter still more certain, the shanks of the blades are twin-*half*-flanged, with inverted angular edges, as shown in the sectional elevation, and in the plan that the boss is made to correspond. The gain by the two modes of securing the blades is that the studs, bolts, and nuts, as now generally used, can be omitted entirely.

To cause the blades to make the partial rotation on their seats, that is necessary to place them in the required positions, the shank-keys are connected by links and pins to the screwed collar *within* the boss. This collar surrounds a hollow-screwed-tube that

fits on the parallel portion of the boss that surrounds the shaft. The aft end of the tube is grooved, forming double collars, and receives between them a brake-band, to which is fitted a stop-rod and an indicator-rod as shown. Now the brake-band is the entire cause alluded to, which is this, that on screwing the stop-rod down against the *loose* or upper portion of the brake, the looped portion below presses also in the groove, and thus the hollow-screwed-tube is held still; and by that means when the shaft revolves, the screwed-collar moves in a coincident direction, and the blades are simultaneously turned on their seats. The grooved portion has also an eccentric groove in it, into which the end of the indicator-rod rests, and should the brake permit any slip; that occurrence would be indicated by the rise and fall of the rod, and thus if it were in connexion with any contrivance in the engine-room, the person in charge could observe the recording of the fact.

It must be understood also that the brake-band must be released directly the collar is at either extremity of the screw on which it works; as the use of the brake is to alter the angles of the blades only, and *not* to hold them in position.

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